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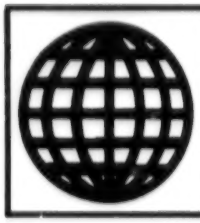

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Microacceleration Conditions, Gravity Sensitivity, and Methods of Analysis of Production Experiments Performed in Weightlessness

957Q0021A Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 1 Feb 94] pp 22-36

[Article by V. I. Polezhayev; UDC 532.013.4: 531.51: 629.7]

[FBIS Abstract] A survey is made of results obtained primarily in the past 2-3 years from measurements and calculations of space-time changes in microaccelerations and from research done on the gravity sensitivity of processes associated with convective heat/mass transfer. The researcher points out that, for determining microaccelerations in the context of theoretical models, conditions in which there is a permanent weak force field—i.e., $\mathbf{n}/g_0 << 1$, where g_0 is the acceleration of the Earth's force of gravity—are more realistic than the classical notion of $\mathbf{n} = 0$. Also surveyed are new methods developed at the Laboratory of Mathematical and Physical Modeling in Hydromechanics of the Academy's Institute of Problems of Mechanics for the analysis of microgravity experiments. Primary attention is focused on the day-to-day use of information regarding the space-time changes and on model development and the problems associated with their application to the analysis of crystal-growth experiments. The researcher here discusses the use of the COMGA system based on Navier-Stokes equations for rapid analysis of convective processes associated with weightlessness, as well as the possibility of estimating microaccelerations on the basis of the temperature changes in a volume of fluid being heated (i.e., convection sensor). Figures 13, references 43: 15 Russian, 28 Western.

Production Equipment for the Unmanned Foton Satellite and Some Experimental Results

957Q0021B Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 12 Jan 94] pp 37-45

[Article by I. V. Barmin, A. S. Senchenkov; UDC 532.78: 629.785]

[FBIS Abstract] The Splav Technical Center of the General Machine-Building Design Bureau has been creating onboard equipment for the production of inorganic materials and biologically active substances in microgravity since 1976, and the Center's Zona-4 unit for growing crystals is currently in use aboard Foton satellites. The accelerations acting on the unit were measured in October 1992 with two assemblies: one measuring the high-frequency component (vibrational accelerations with an amplitude of from 3×10^{-3} m/s^2 to 3 m/s^2, or 3×10^{-4} to 0.3 g_0, at 2-200 Hz), the other measuring the low-frequency component (1×10^{-6} to 1×10^{-2} g_0, at 0-2 Hz). Crucible-free zone melting has been used to produce single crystals of pure and alloyed germanium 15-20 mm in diameter and 60 mm long, as well as indium and gallium antimonide crystals of the same size. The researchers have also developed a special method for the ground-based setup of space experiments. A technique using a moving heater has been used in crystal-growth experiments since 1991, and CdTe, CdSeTe, and CdZnTe crystals have been produced on Foton-8 with that technique. To control the flow of the melt in the zone the researchers are using permanent magnets that create a 160 mT axial magnetic field in the fluid zone. The principal effect produced is that flow changes from oscillating to laminar. A French-Russian experiment aboard Foton-9 will employ that kind of field in the context of crucible-free zone melting in the spring of 1994. Figures 5, references 7: 2 Russian, 5 Western.

Producing Layered Semiconductor Materials in Microgravity and Under Slow Cell Rotation

957Q0021C Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 25 Jan 94] pp 46-52

[Article by N. A. Verezub, V. I. Polezhayev; UDC 532.529.2+ 548.25]

[FBIS Abstract] A semiconductor's characteristics depend on gravity-sensitive processes that take place in the melt as the semiconductor is being produced. The fact that those processes are little studied prompted the researchers here to formulate simple production methods whose results can be predicted with mathematical modeling. When epitaxial layers are being grown, convection occurs because of the density irregularities that result from the depletion of the solution/melt by the component being crystallized. For A^3-A^3B^5 systems, concentration convection dominates in the melt. The model presented here is a model of liquid-phase epitaxy constructed for the production of layers from the limited volume of a saturated solution/melt in isotherms on two substrates. The flow and concentration fields are two-dimensional; except for concentration, the physicochemical parameters of the solution/melt are constant; the temeperature dependence of the concentration is linear; the initial surface of the substrates is smooth; the change in field dimensions as a result of growth of the layers is disregarded; crystallization takes place on the substrates only; and kinetic phenomena at the boundary between the substrate and the melt are disregarded. The modeling was based on nonstationary Navier-Stokes equations in the Boissinesq approximation. The numerical modeling of the convection and mass transfer used parameters typical of epitaxial growth of A^3B^5 semiconductor compounds (see Polezhayev et al., Konvektivnyye protsessy v nevesomosti [Convective Processes in Weightlessness], Nauka, 1991, 240 pp). When the substrates are placed horizontally ($\varphi = 0$) in the melt, Rayleigh-Benard cell convection takes place. Vertical placement of the substrates results in a plane-parallel flow, and the change to microgravity reduces the irregularity for the entire length of the substrates. Changing the orientation of the growth cell results in Rayleigh-Benard convection being replaced primarily by a plane-parallel motion. The researchers note that the effect of orientation on the configuration of the epitaxial layers makes it possible to use the dynamic variation in the angle φ over the course of the experiment as a controlling factor of the liquid-phase epitaxy. Figures 6, references 14: 9 Russian, 5 Western.

Convective Flows in a Cylindrical Fluid Zone in a High-Frequency Vibration Field

957Q0021D Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 5 Jan 94] pp 53-61

[Article by G. Z. Gershuni, D. V. Lyubimov, T. P. Lyubimova, B. Roux; UDC 532.5.013.4:536.25]

[FBIS Abstract] Most of the research involving vibrational convection has focused on the behavior of a fluid that completely fills a rigid-walled vessel characterized by translational vibrations. But when there are free fluid surfaces, a surging motion exists, and vibrational convection is much stronger. D. V. Lyubimov, in an earlier work ("Thermovibrational flows in a fluid with a free surface," MICROGRAVITY QUARTERLY, 1994, Vol 4, No 1), formulated a step-by-step general approach for describing the behavior of nonuniform media in the presence of hf vibrations. That approach is used here to study the behavior of a nonisothermal fluid in a cylindrical fluid zone with a free lateral surface in a field of hf axial vibrations. The fluid in the vessel, which produces linearly polarized translational vibrations, is unevenly heated. The researchers examine only axisymmetric solutions in which only the radial and axial components of fluctuating and averaged rates are different from zero. Numerical results are presented for case in which the thermocapillary effect on the free boundary is absent (the Marangoni number is 0). Two vibrational mechanisms for the generation of an averaged current are operative (the Shlikhting isothermal mechanism and a thermovibrational convective current). Figures 4, references 7: 3 Russian, 4 Western.

Study of the Effect of Weightlessness on Convection and Mass Transfer When Crystals Are Grown From Aqueous Solutions

957Q0021E Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 12 Jan 94] pp 62-66

[Article by V. A. Braylovskaya, V. V. Zilberberg, L. V. Feoktistova; UDC 532.5.013.4:536.25:548.512]

[FBIS Abstract] The hydromechanics of microgravity may be used to improve the technology associated with the rapid growth of KDP crystals for laser optics. As essential element of that technology when used on the ground is the intense feed of solution to the crystal surface, and one of the requirements for the solution dynamics is the creation of a uniform concentration boundary layer at the solution-crystal interface. Since, on the ground, free convection produces a considerable lack of uniformity in the concentration field near the crystal surface, crystal quality may be improved if the crystal is grown in conditions near those of weightlessness. Mathematical modeling of the processes involved in reduced gravity makes it possible to identify the features of the interaction of natural and forced convection in the context of fairly low solution rates. The researchers here compare the results of modeling for normal gravity and for weightlessness. An important result of the work reported here is the estimate provided of the time it takes for the development of instability (40-50 s). Over that span of time, an elementary step on the growth surface covers about 1 μm, and that is enough for the formation of a defect in the crystal. Comparing the rates of motion of the solution in the boundary layer makes it possible to estimate the intensity of the forced dynamics needed for suppressing the natural dynamics. The result obtained (U is approx. 5×10^{-3} m/s) coincides in order of magnitude to the value for v_0 obtained by Brailovskaya et al ("Mixed solutal convection above the growing crystal surface," PROC. EUROP. SEMINAR 30, Orsay, France, 1992, pp 167-168) for a different geometry (a single-nozzle feed) for the normal fall of the solution onto the surface of the growing crystal. Convection on the ground produces local secondary structures that are a potential source of defects in low-temperature growth, but that can be suppressed if the hydrodynamics near the growing surface are properly set up. Figures 4, references 12: 7 Russian, 5 Western.

Experimental and Theoretical Study of Thermal Convection in a Ground Model of a Convective Sensor

957Q0021F Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 3 Feb 94] pp 67-75

[Article by G. P. Bogatyrev, M. K. Yermakov, A. I. Ivanov, S. A. Nikitin, D. S. Pavlovskiy, V. I. Polezhayev, G. F. Putin, S. f. Savin; UDC 532.5.013.4:536.25]

[FBIS Abstract] In orbital flight, the acceleration vector varies widely in magnitude and direction, making modeling of nonstationary three-dimensional flows in actual weightlessness difficult. Because of the low residual accelerations, gravity convection aboard space vehicles must be relatively weak. Full-scale experiments that determine the presence of such convection indirectly have produced contradictory results, a fact that makes a direct in-orbit experiment seem necessary. The gravity- and inertia-sensitivity of flows in nonisothermal fluid and gaseous media makes it possible to suggest a method that measures microaccelerations aboard a space vehicen the basis of the recording of the temperature stratification that is due to free convection. Some researchers have recorded weak convection by observing thermal-front propagation between coaxial cylinders. The use of a convective sensor is considered quite promising for measuring the magnitude and direction of the low-frequency force-field components that most instruments currently used cannot measure. The researchers here present the results of laboratory modeling of the measurement of microaccelerations on the basis of observations of the convective movement of air in a sensor that consists of a cubical cavity. Navier-Stokes equations in a Boissinesq approximation in the right-hand system of coordinates *xyz* bound to the cubical cavity moving at some angular velocity around an immobile axis are used. The researchers analyze the relationships between, on the one hand, the temperature differential between two points in the cavity and, on the other, the angle of inclination, the applied vertical temperature gradient, the oscillation rate of the cavity, and the fluctuations in heating intensity. The

results of the testing of the model were in agreement with the model itself in that they showed that the transverse temperature difference consists in strictly sinusoidal fluctuations with the same frequency as the frequency of oscillation. When frequency rises, there was a gradual reduction in amplitude until the oscillations were damped at $f_1^* = 0.77$ Hz, after which amplitude began to rise. Figures 8, references 4 (Russian).

Microconvection in a Vertical Layer

957Q0021G Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 18 Jan 94] pp 76-84

[Article by V. V. Pukhnachev; UDC 532.517.013.4: 536.252]

[FBIS Abstract] With reduced gravity, the Oberbeck-Boissinesq approximation cannot be used to describe thermal gravity-induced convection. Assuming the isothermal noncompressibility of a fluid, a new model is proposed in which the velocity vector is no longer solenoidal. The researchers here use that model to analyze the convective motion in a vertical layer on whose solid edges a thermal flow is assigned that is time-dependent only. The researchers assume the following: fluid density ρ is a function of temperature only; the potential energy of the fluid in the gravity field is much smaller than its internal energy; the dissipation of the kinetic energy associated with the motion is only slightly smaller than the contribution of the diffusion flow of heat to the energy equation; the viscosity coefficient μ, the thermal conductivity coefficient k, and the specific thermal capacity of the fluid c are constant. The researchers conclude that the nonsolenoidal nature of the velocity does not lead to any appreciable restructuring of the stationary convection. In addition, the pictures of the nonstationary convective flows calculated in the context of the classical model and the new model are distinctly different from each other. Figures 4, references 7: 6 Russian, 1 Western.

Secondary Flows in a Layer With a Free Surface

957Q0021H Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 19 Jan 94] pp 85-98

[Article by D. S. Pavlovskiy; UDC 532.517.2.013.4: 536.25]

[FBIS Abstract] Loss of stability is examined for the plane-parallel flow of an uncompressed, viscous, thermal-conducting fluid in a horizontal layer in which there is a longitudinal temperature gradient. Various conditions are set for fluid velocity and temperature on the horizontal boundaries of the layer. The lower surface of the layer is considered solid, the upper surface, free. The surface tension coefficient on the upper surface is a linear function of temperature, i.e., acting on that surface is a thermocapillary force resulting from the relationship that exists between the surface tension coefficient and temperature. Since adiabatic boundary conditions for temperature serve as a rather good approximation for fluids with a high thermal conductivity coefficient, the region with low Prandtl numbers was examined, which is typical of liquid metals and melts of semiconductors. Both boundaries of the layer are thermally insulated. Depending on other determining parameters, the critical value for the temperature gradient—where flow conditions change and fluctuations arise—is found with techniques from the linear theory of stability. The secondary flows that appear after the loss of stability are found in an analysis of a complete nonlinear problem by means of breaking the solution down into a series involving degrees beyond criticality in the vicinity of the bifurcation point. Three types of secondary flows are studied: plane two-dimensional waves propagating along the temperature gradient; plane waves running at some angle to the gradient; and three-dimensional waves propagating along the gradient. The researchers also describe a numerical solution method based on polynomial approximation. Figures 8, references 11: 5 Russian, 6 Western.

Convection in an Oscillating Field of Forces and Microgravity

957Q0021I Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 12 Jan 94] pp 99-106

[Article by S. Ya. Gertsenshteyn, A. I. Rakhmanov; UDC 532.5.013.4:536.25]

[FBIS Abstract] Convection in a flat layer of viscous fluid rotating around a horizontal axis at a constant angular velocity $\Omega = (0, -\Omega, 0)$ is examined, as is convection in a flat horizontal layer of viscous fluid oscillating according to $e = -c \sin \Omega t$ in the direction of vector $\mathbf{e}$, which lies in the xz plane and forms an arbitrary angle φ with the x axis. In both cases, a layer with thickness d is located in a field of gravity: the boundaries of the layer, on which a constant temperature difference δT is maintained, are assumed to be isothermal, impenetrable, and free of tangential stresses. The researchers examine instances in which the oscillation of an external force is generated by rotation around a horizontal axis or by vibration in an arbitrary direction. Using Navier-Stokes equations in a Boissinesq approximation to describe the motions of the fluid, they identify flows that appear the layer when there is a transverse temperature gradient, they find the boundaries of stability for those flows, and they study the supercritical conditions of motion. For large Taylor numbers, the researchers use an averaging method that makes it possible to move from a study of the stability of the main, periodic flows to a study of the stability the position of equilibrium of the averaged equations of motion. Secondary conditions of motion that appear as a result of a loss of stability are also studied, in the context of two-dimensional nonlinear nonaveraged equations. Figures 5, references 8: 6 Russian, 2 Western.

Interaction of Thermovibrational and Thermocapillary Mechanisms of Convection

957Q0021J Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 15 Feb 94] pp 107-121

[Article by R. V. Birikh, V. A. Briskman, A. L. Zuyev, V. I. Chernatynskiy, V. I. Yakushin; UDC 532.51.013.4: 536.25]

[FBIS Abstract] Variable inertial forces, specifically those caused by vibrations, and thermocapillary forces are the principal sources of heat-and-mass transfer aboard space vehicles in actual weightlessness. The literature has devoted considerable attention to each of the factors. But until recently, there were no studies of the interaction of the two factors, and, as the first studies have shown, the interaction of the two do not simply boil down to superposition. The researchers here set out to identify specific vibrational-thermocapillary phenomena that appear as a result of the combination of a time-averaged volumetric thermovibrational force and thermocapillary force on an isothermal surface of a fluid. They also sought to ascertain the possibility of using high-frequency vibrations to control thermocapillary convection. Specifically, they focused on problems in which, isothermically, the fluid can be considered as moving along with the vibrating vessel. In high-frequency approximation, the thermovibrational forces were recorded for instances in which isothermal mixing of the fluid is not essential. The researchers formulate a problem involving high-frequency vibrational-thermocapillary convection and present a brief survey of some of the work that has been done in the field. The latest results of such work are addressed in more detail, i.e., Marangoni instability of the equilibrium of a flat layer exposed to transverse vibrations, as well as the effect of thermocapillary forces on the stability of thermovibrational convection in a square cavity. Figures 10, references 32: 19 Russian, 13 Western.

Features of the Behavior of a Fluid and a Fluid-Gas System Under Conditions Close to Weightlessness

957Q0021K Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 24 Dec 93] pp 122-128

[Article by A. M. Vetoshkin, A. V. Korolkov, V. V. Savichev; UDC 532.5.013.4:536.25]

[FBIS Abstract] Results are presented from work involving the solution of problems that arise in the study of the behavior of a fluid or a fluid-gas system under conditions close to those aboard a space vehicle in near-Earth orbit. The researchers point out that a study of the features of the behavior of a fluid in a filled vessel in microgravity has been done numerically on the basis of the solution of a system of differential transfer equations. Data have been obtained on the structure and intensity of flow in thermal gravity-induced convection for internal, external, and coupled problems in vessels of various shapes and under various laws involving the variation of the acceleration vector. The principal result of such research has been to identify the field of values for the relative angular velocity of the change in direction of the acceleration vector at which the role of thermal gravity-induced convection remains substantial in heat transfer. The researchers assert that the spatial evolutions of the acceleration vector aboard a space vehicle create the conditions for the features studied. Those features are seen in the increase in the intensity of the convective motion and heat exchange in a vessel filled with a fluid and in the production of arbitrary relative displacements of the fluid or gas in a partially filled vessel. Figures 5, references 8 (Russian).

Numerical Study of the Behavior of a Fluid-Gas System in a Variable Field of the Acceleration Vector With Through-Computation

957Q0021L Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 24 Dec 93] pp 129-134

[Article by A. V. Korolkov; UDC 532.516:519.63]

[FBIS Abstract] Spatial evolutions of the local acceleration vector aboard a space vehicle produce arbitrary mutual displacements of fluid and gas. To study the behavior of fluid in such complex conditions requires the use of special computation algorithms capable of tracking changes in the position of the interface surface of the media. Most of the research done to date on the behavior of a fluid-gas system has been based on assumptions that limit the possible displacements of the fluid surface. To solve problems involving arbitrary displacements of fluid and gas, it is best to use a through-computation algorithm. Such an algorithm can be successful in solving problems involving the motion of a fluid in a container with moving boundaries. The researchers focus on a cylindrical container with a rectangular base. The problem they address is a coupled problem, and on the moving interface of the media are conditions coupling velocities and temperature. The walls are immobile and impenetrable. The fluid and the gas are not compressed, and their parameters are constant. In describing buoyancy forces, only the relationship of density to temperature is taken into consideration. Figures 5, references 11: 9 Russian, 2 Western.

Formation of Bubbles in a Tellurium-Silicon Melt in Microgravity and Their Dynamics

957Q0021M Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 29 Dec 93] pp 135-141

[Article by B. T. Melekh, I. I. Farbshteyn, V. P. Shalimov, N. K. Shulga, S. V. Yakimov, Physical Technical Institute imeni A. F. Ioffe, Russian Academy of Sciences, St. Petersburg; UDC 532.529.6:546.24/28:620.1:629.7]

[FBIS Abstract] The production of the glass alloy $Te_{80}Si_{20}$ in microgravity is part of an experiment performed on the Mir station in the ALKUTEST-2 program. Studies of the effect of gravity as a production factor on the properties of objects with an amorphous structure is also of interest from the standpoint of gas generation, since the presence and shape of gas inclusions greatly affects the practical application of glass materials. This paper presents a comparison of the nature of gas inclusions in samples produced in microgravity and in samples produced on the ground. It also analyzes the conditions attending bubble formation and dynamics for various levels of gravity. The researchers found inclusions with the same shape as that of gas bubbles in a $Te_{80}Si_{20}$ sample that was solidified in microgravity. Similar bubbles formed in the ground-produced ingot. Analysis of the possibilities of gas generation in a $Te_{80}Si_{20}$

melt suggests that such generation is due to the evaporation of telluride; the inception of a new phase takes place under conditions of thermodynamic equilibrium. According to theoretical estimates used by the researchers, the formation of bubbles in microgravity should occur much easier and much more intensely than on the ground. But those estimates, for lack of data, did not take into consideration the possibility of a substantial reduction in surface tension at the edge of a small bubble-nucleus. In experiment, no differences were found between bubble formation processes in space and those on the ground. The researchers suggest that there was no advanced convection in either environment. They found gravity-sensitive effects in the processes of gas generation and bubble dynamics in the melt, with no convection. Figures 1, references 13: 8 Russian, 5 Western.

Natural Convection and Temperature Stratification in a Cryogenic Fuel Tank in Microgravity

957Q0021N Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 12 Jan 94] pp 142-149

[Article by S. G. Cherkasov; UDC 532.51.013.4:536.25]

[FBIS Abstract] The processes that are observed in space-vehicle fuel tanks are important for the practical application of hydromechanics in microgravity. The pressure in a tank filled with a cryogenic fluid and its vapors is determined by the temperature of the surface of the interface, a temperature that, for a number of reasons, can exceed considerably the average mass temperature of the fluid. For that reason, the rate of pressure increase may vary with the distribution of temperature in the liquid phase of the fuel. One factor determining temperature stratification of cryogenic fuel is natural convection, and in microgravity that convection can be very intense. The model presented here for calculating temperature stratification of a cryogenic fuel is based on the solution of a coupled problem for boundary layer and nucleus via the use of integrated equations for a freely convective boundary layer. The researchers compares the results of their calculations with numerical solutions of Navier-Stokes equations and with experimental data. Figures 4, references 11: 10 Russian, 1 Western.

Bifurcation of Solutions and Calculation and Asymptotics of Neutral Curves of Monotonic Loss of Stability in a Problem Involving Concentration Convection in an Electrical Field

957Q0021O Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 7 May 93] pp 150-157

[Article by M. Yu. Zhukov, O. A. Tsyvenkova; UDC 532.51.013.4;536.24.01;537.363]

[FBIS Abstract] In studying the effects that the physical characteristics of an admixture concentrated in an electrical field and its location have on the occurrence of instability, the researchers considered a flat horizontal layer filled with a buffer solution. The admixture is released from the solution in a given region of the layer by an electrical field. The conductivity of the solution and the electrophoretic mobility of the admixture are considered to be dependent on the vertical coordinate z only. A system of equations in the Oberbeck-Boissinesq approximation describes the isoelectrofocusing and, in dimensionless variables, takes the form of equations presented by the same two researchers in an earlier paper ("Numerical study of the effect of the zone of a substance on concentration convection in isoelectrofocusing," KOSMICH. NAUKA I TEKHNIKA, 1989, No 4, pp 30-34). Primary attention in the construction of a convection model is focused on concentration effects. Joule heat release is assumed to be negligible, and fluid temperature, constant. Since the presence of a δ coefficient $e^{UH(z)}$ in the equations used to determine the critical parameters of monotonic stability loss complicated the application of numerical integration methods even at $U > 100$, the researchers presented a formal technique for constructing the asymptotics of the eigenvalues at $U \to \infty$. Figures 2, references 8 (Russian).

Damping of Nonlinear Oscillations of a Viscous Fluid That Partially Fills a Vessel

957Q0021P Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 94 [manuscript submitted 20 Apr 93] pp 158-162

[Article by I. B. Bogoryad, G. V. Khristenko; UDC 532.595+532.516]

[FBIS Abstract] Results are presented from a numerical experiment involving the determination of the damping of free axisymmetric oscillations of a viscous, noncompressed fluid that partially fills an upright circular cylinder via the finite-differences method. No constraints are imposed in terms of smallness of amplitudes or viscous friction. The experiment is performed for Reynolds numbers at the lower boundary of applicability of the approximation of the laminar boundary-layer theory and for finite oscillation amplitudes. The influence of nonlinear effects on the magnitude of estimates of the logarithmic decrement of the oscillations is discussed in the context of quantitative estimates. The mechanism of the effect of the convective members of Navier-Stokes equations on the energy distance of free-surface oscillations is examined. Figures 2, references 11: 9 Russian, 2 Western.

Possible Space Activities for Next 25 Years Outlined

957Q0026 Moscow ZEMLYA I VSELENNAYA in Russian No 5, Sep-Oct 94 pp 64-71

[Article by L. V. Leskov, doctor of physics-mathematics, under the rubric "Hypotheses, Discussions, Suggestions: The Next 25 Years of Peaceful Space: an Attempt at a Forecast"; first two paragraphs are source introduction]

[FBIS Translated Text] **Thirty-seven years separate us from the beginning of the space age. Twenty-five years ago, man set foot on the surface of the Moon for the first time ever. Unmanned interplanetary probes have performed close-up studies of almost all the planets of the solar system, and space vehicles have landed more than once on Venus and**

Mars. Space activities have already contributed much to various sectors of the national economy.

But what will space activities consist of in the coming decades? The author of this article lays out his own vision of that problem.

Why Is This Kind of Forecast Needed?

Upon entering our lives, space activities assumed a place entirely worthy of note alongside electricity, aviation, and television; but that place is, nevertheless, a special place. **First,** with the development of such activities, man has gained an opportunity to extend his technical activities to a completely new production environment—space. **Second,** one of the chief areas of space activities is geared to solving problems involving ecology and environmental protection, the significance of which today is extremely great for the future civilizations of the Earth. And finally, third, space activities themselves are rapidly becoming something that all of mankind is involved in: most of today's large space programs are based on international division of labor and collaboration.

But there are also inhibiting factors that are forcing governments and commercial structures to be careful in terms of financing—which stems from the high cost of most of the space programs, the lengthy period it takes to execute them, and the relatively large risk involved. In light of the positive aspects, as well as the risk factors, one must acknowledge that a long-term forecast of such activity in the context of the world economy becomes very significant to the conduct of proper scientific-technical and financial policy.

Space Activities in the Year 2020: A General Description

If space activities continue to grow at the rate they are growing today, the commercial transactions of the space-services market will reach $100 billion (in 1993 prices) by 2020, and space activities will gain fundamentally new frontiers. Highly efficient **next-generation space transportation systems** will be developed, and there will be considerable progress in the creation of **space-based energy supply systems** and **in the use of extraterrestrial resources.**

Satellite systems for communications and remote sensing of the Earth—whose high rate of payback to the national economy is virtually proven at this point in time—are expected, obviously, to be the continued focus of vigorous development. But the improvement of **space-based information systems** of subsequent generations depends primarily on the success achieved in electronics and optoelectronics and on the progress made in the development of computer hardware and artificial intellect systems. The economic return of those systems will be elevated by a change to new carriers.

Services that use satellite communications hardware to accommodate the occupational and general-education training system, information data banks, and medical networks will be expanded, as will services for transportation systems and individual communications hardware and, among many other things, the video-assisted repair of complicated equipment. In that context, one should expect both a continued increase in the percentage of commercial capital and an expansion of the types of services offered.

Unless there are radical changes in the development of the world civilization, the interaction between the state sector and leading enterprises of the aerospace and electronics industries will remain as it is. Keeping the contract system for executing national space programs in the hands of the governments allows them to control scientific-technical progress and mobilize scientific-technical and production potential for the most urgently needed areas.

A winner in that kind of interaction is also the commercial sector: filling state orders enables enterprises to effect a high level of technological feasibility for the products they manufacture and, based on that, subsequent diversification of production. For that reason, even if the rate of return to an enterprise in the context of a state contract stays at a middling level, the actual profits will remain rather high.

The **commercialization** of space activities, with government control of the strategic directions taken by such activities left intact, will help them to grow rapids and produce higher rates of return. More likely than not, **satellite communications** will play a leading role in that process. By some estimates, satellite communications by the year 2000 will account for roughly 90 percent of all space activities.

More commercial activity should also be expected in the **remote sensing of the Earth, in-orbit production of materials, and the development of a system of aerospace activity with ground support.**

And here's another important feature we should expect of the space activity of the 21st century: further expansion and reinforcement of various forms of international collaboration. Space activities will help to form a single Earth economy and to assert the unity of all mankind.

The important advantages of international collaboration are seen in programs like "Mission to Planet Earth" (ZEMLYA I VSELENNAYA, 1992, No. 1, p. 64). A broad network of various kinds of satellite systems in various orbits—polar, geostationary, and equatorial—will be created for that. National and regional ground-based services of an infrastructure supporting the day-to-day use of satellite-derived information will also grow.

Strategic Directions of Space Activity

Transportation systems. The 21st century will see the development of new expendable launch vehicles of light, medium, and heavy classes. They will be distinguished by the following features: high level of reliability, efficiency, and better environmental safety.

It is not out of the question that the launchers of a new generation will be equipped with *hybrid rocket engines.* The *liquid-fuel* and *solid-propellant* rocket engines now in use have a number of serious drawbacks. With liquid-fuel rocket engines, accidents can happen that are due to, for example, spontaneous contact between fuel and oxidizer. With solid-propellant engines, accidents can happen if the

fuel doesn't burn properly in the nozzle (as in the Challenger accident). In addition, it is rather difficult to lower the cost of those engines, and certain types of fuel used in them are highly toxic.

Free of those drawbacks, hybrid rocket engines (liquid oxidizer, solid propellant) have potential advantages that can ensure greater reliability, efficiency, and safety.

Another class of promising space transportation systems that will undoubtedly appear in the 21st century is the spaceplane. Its advantages are also well-known: their flights are highly economical and efficient, the spaceplanes can enter a broad range of near-Earth orbits, and the spaceplanes can use ordinary airfields. Those advantages are so substantial that people are calling the creation of spaceplanes the second space revolution. Work on spaceplanes is under way in various countries (**X-30** in the United States, **Hotol** in Great Britain, **Saenger** in Germany [ZEMLYA I VSELENNAYA, 1989, No. 6, p. 75], and **Hermes** in France [ZEMLYA I VSELENNAYA, 1993, No. 1, p. 40]). Such work was also begun in Russia: the **VKS** [spaceplane] project, developed at the NPO Molniya under the direction of G. Ye. Lozino-Lozinskiy (ZEMLYA I VSELENNAYA, 1991, No. 3, p. 19). One version of that project assumes joint work with the creators of the British Hotol stage.

Another project, also under development in Russia, was started by the association Zemlya I Kosmonavtika under the direction of the pilot-cosmonaut I. P. Volk. The spaceplane is expected to use liquid hydrogen for engine fuel, and atmospheric oxygen will serve as the oxidizer.

After space 20-500 kW solar power systems are created, *electric rocket engines* will begin to be used; they will be capable of making cargo transport operations highly economical in near-Earth space and in other parts of the solar system. Since we can expect the development of solar arrays that are more economical and efficient than those currently in use, the field of practical use of electric rocket engines in the 21st century will be constantly expanding.

As for *powerful nuclear reactors* combined with electric sustainer engines, as well as *nuclear-propulsion engines*, they are not likely to be used in the early 21st century because it is still not clear how to ensure adequate safety with such systems. Although the creation of powerful nuclear and nuclear-electric sustainer engines does not seem very likely for now, the broad use of radioisotope nuclear reactors with thermoelectric and thermionic converters is not out of the question. Certain domestic satellites of the Kosmos series are already equipped with Topaz reactors that belong to that class.

Two other types of promising transportation systems whose practical use may begin in the 21st century are well-known—**cable systems** and **shock guns.** Cable systems (ZEMLYA I VSELENNAYA, 1993, No. 3) would make transport operations in near-Earth orbits considerably easier (we could get along without space towcraft, which would simplify the design of spacecraft and lower transportation costs).

The largest two-stage, light-gas gun in the world is being built at the Livermore Laboratory (U.S.). Expectations are that it will be able to fire a 5-kg projectile at speeds of up to 4 km/s. A number of fundamentally new solutions that improve operational efficiency are used in its design.

Guns build on those principles will be able to place as much as 90 percent of all cargoes into near-Earth orbit (with an acceleration of 1.5×10^3 **g**, at a cost of only about $500/kg. Another advantage of such a gun is that it produces considerably less of an effect on the environment than does the launch of a rocket. Other versions of guns designed to send payloads into space are also possible (electromagnetic acceleration, hybrid guns, closed-shaft acceleration, etc.). But the research on those guns is still in a stage of very early preliminary design.

The changeover from traditional launch vehicles to transportation systems based on other physical principles will make the construction of high-capacity space power systems in near-Earth orbits considerably easier and will meet the necessary requirements in terms of environmental safety.

Space-based power systems. At present, the joint Russian-American venture International Energy Technologies is performing design research on the creation of nuclear reactor units with a capacity of 30-40 kW for a lunar base and for a Mars mission. The immense amount of experimental data that our country has accumulated on reactors of that class makes it possible to conclude that all the physical and technical problems facing the developers can be resolved successfully. But it is difficult to guarantee the safety of such reactors, and if an accident were to occur when they are being lifted into space, the consequences could be catastrophic. And that is why the forecast of the possibility of their use is a only a cautious one.

It is quite likely that, in the 21st century, one of the main sources of energy for Earth will be *space-based solar electric power stations* that will pollute the environment considerably less than do existing power stations and will not lead to accidents like the accident at Chernobyl. The main problems associated with such space-based stations involve the need to development the appropriate component base and to place cargoes weighing tens of thousands of tons into space. The U.S. Department of Energy and NASA are considering the possibility of building 60 space-based solar electric power stations (5 GW each) in geostationary orbit. At a frequency of 2.45 GHz, the losses of microwave energy in the Earth's atmosphere cannot exceed an average of 1 percent of the power produced. The high efficiency of the conversion of microwave energy to ground-based rectification (about 90 percent) helps to prevent "thermal pollution" of the Earth.

In the early 21st century, the primary focus of attention in the context of the problem of space-based solar electric power stations will be on the solution of several interrelated problems:

—improving the component base

—researching safety issues

—developing possible insertion systems

—setting up and performing space experiments with models of space-based solar electric power stations with capacities on the order of 100 kW and 10 MW

An experiment involving the space transmission of 1-kW UHF emissions has been set up in Japan, and experiments with higher powers are slated for the early 21st century. The creation of a 1-GW space-based solar electric power station will enable interorbit transfers in near-Earth space based on new principles ("space trolleys").

Another promising area of space power-engineering whose time will come in the 21st century involves *orbital reflectors* designed to illuminate regions of the Earth. Design research for that has been done in our country and abroad. Among the lesser-studied possibilities for the practical application of such systems are mineral prospecting based on the employment of long-wave electromagnetic radiation to penetrate the Earth's interior; the use of film reflectors to remove "space trash" from near-Earth space; and the development of transportation systems equipped with a space sail.

The first experiment involving the illumination of regions of the Earth with a 20-m aluminized Mylar reflector mounted aboard a Progress cargo-transport craft was performed in February 1993 (ZEMLYA I VSELENNAYA, 1994, No. 1, p. 3). It is interesting that the experiment evokes protests in the domestic press from certain highly placed ecologists who apparently understood absolutely nothing about the issue.

Extraterrestrial resources. A higher level of technical support, more financing, and international division of labor are making it possible to implement a number of programs aimed at studying and developing extraterrestrial resources. The most significant of those projects are the *creation of a research base on the Moon* and the *set up of a mission to Mars*. The implementation of those projects will be immensely easier if they are international from the outset and if the first of the two projects [lunar] precedes the other.

The prospects for *developing the Moon* in the 21st century seem quite broad: research, the construction of various lunar enterprises, a mining industry to deliver raw minerals to near-Earth production complexes that are part of a system for the erection of a network of space-based solar electric power stations in geostationary orbit, the extraction of the helium-3 isotope, and the set up of tourist flights.

Only part of that program may be implemented before 2020. The first stage of the program will revive a detailed study of the Moon's surface with unmanned vehicles: detailed plotting of topographic and geological maps, and a lunar rover for studying the physical and chemical properties of the soil. The next stage will involve the assembly of a solar array of sufficiently high power. After that, we can begin the construction of a long-term base capable of functioning on, for the most part, internal resources, and we can manufacture solar arrays, glass, and electronics components out of silicon.

The main construction material on the Moon is expected to be concrete, the raw material for which could be the mineral anortinosite, 20 percent of which is SiO_2; aluminosilicates can also be used. By heating the mineral helmenite to 800°C, one can obtain oxygen. Producing water requires bringing hydrogen from Earth, although it is possible that hydrogen is contained in lava flows or in the surface layer of the lunar soil. The implementation of the first stages of the program is slated to begin even before 2020. One problem that will be resolved in the early stages of the lunar program involves a study of the possibility of the industrial extraction on the Moon of the helium-3 isotope, a future promising raw material for the production of energy in thermonuclear fusion installations. The small amount of gravity on the Moon and the absence of an atmosphere will make it possible to use electromagnetic mass accelerators and cable systems to support transport operations.

The programs for flights to Mars by unmanned vehicles and, around the year 2020, a manned expedition have already been studied in rather great detail. But, in any case, before than can happen, two tasks must be performed: the creation of a new heavy launcher, and the creation of a large, permanent orbital station. The suggestion to use the Energiya launch vehicle for those purposes is hardly feasible, and by the beginning of the 21st century, its component base will be out of date.

Space ecology. One large environmental program—Mission to Planet Earth, in which the United States, Western Europe, and Japan are participating—is slated for 1996-2011; there is no doubt that, with time, the decision will be made to continue and expand it. That program plans to place unmanned vehicles in circumpolar orbit, geostationary orbit, and equatorial orbit. The Earth's surface will be studied in order to determine the results of man's stress on and contact with the plant and animal world, as well as other ecological problems.

The next large program involves the **removal of radioactive waste from the Earth** (ZEMLYA I VSELENNAYA, 1992, No. 5; 1993, Nos. 5 and 6).

By around the year 2020, the amount of radioactive waste generated in the world will be on the order of 100 kg annually. The problem of reliably burying them in the Earth is quite a serious problem: the half-life of some isotopes is greater than 1,000 years. There are also extremely hazardous short-lived isotopes with half-lives of less than 10 years. For that reason, probably, the most acceptable version, technically speaking, involves heavy actinides with long half-lives being sent into deep space in sealed containers and then dispersed in gaseous form. In such a dispersion, the concentration of radioactive gas is considerably lower than the concentration of hydrogen, and the radiation density will be lower than the radiation density of cosmic rays.

Another area of space ecology involves the **ecology of space activities themselves,** or, in other words, the problem of the harmful effects produced by aerospace systems. One serious bit of work being done in that area is a project called SSPS-2000 [Space-based Solar Power Station 2000], which is being performed in Japan; it is under way and will continue in the 21st century. An experimental 10 MW solar power station is expected to be placed into equatorial

orbit, with an altitude of 1,000 km. The station is expected to be placed in orbit by the Russian Energiya rocket or the French Ariane rocket.

One of the central objectives of the project is to study the ecological effects produced by microwave radiation on the environment. The experiments in SSPS-2000 will make it possible to resolve the question of safety and full-sized gigawatt stations. Perhaps then the psychological barrier that underlies the cautious, guarded attitude of the public toward that new class of energy systems will be overcome.

An important feature of the Japanese SSPS-2000 program is its multilevel nature and its striving from the very outset to consider all possible feedback and to study the damage that the operation of such stations could do to the environment. That approach sets the program dramatically apart from projects in which those aspects are not of primary concern. The SSPS-2000 program stands out as a model for similar projects of the 21st century. Another example of a multilevel program that has an environmental bent is the previously mentioned Mission to Planet Earth. There is no doubt that in the 21st century, the percentage of such operations will grow considerably—such is a requirement of the ecological imperative. That criterion will play an increasingly important role in the selection of promising space transportation systems. In the first stages of the development of such systems, that criterion was virtually unconsidered. By the way, the launch of one, say, Soyuz rocket destroys 220-230 tons of ozone in the Earth's atmosphere.

A very important aspect of such programs is the *study of solar-terrestrial relationships.* The Earth's biosphere owes its origins to the Sun and is linked to processes that occur on the Sun by a multitude of complex relationships that are not at all well studied. One of the most important objectives of the space ecology of the 21st century is the multilevel study of those relationships.

In order to survive, mankind in the 21st century must develop a new strategy for its relationship with the world of nature—a strategy of coevolution. And space research is destined to assume the role of being one of the chief tools for resolving the problems we have alluded to.

Space machine-building. Space hardware, which operates in conditions dramatically different from those on Earth (weightlessness, space vacuum, radiation effects, nonstationary thermal conditions), urgently needs a new approach in the development of space systems. That applies, in particular, to materials and will apply to structural elements that are expected to be produced right on the orbiting industrial complexes. Such tasks were never encountered before in machine building, and their significance in the 21st century will grow substantially.

That will require the development of a new area in science and technology—space machine-building, which is the aggregate of science and production engineering disciplines, as well as production lines, aimed at developing intricate structures and equipment for operation in outer space and on other celestial bodies (the Moon, Mars, Phobos, and the asteroids).

Via feedback, the development of space machine-building will stimulate progress in the Earth's economy and will move the leading technologies and materials into various sectors of industry. For that reason, one important area of space machine-building will be the creation, in near-Earth orbits, of special production complexes for making new materials. Such complexes will be unmanned vehicles, some of which will be man-tended, with the visitors flying to them in reusable spaceplane transports. The current plans to set up the industrial production of materials aboard orbital stations are not likely to be able to be implemented, because of the high level of dynamic interference on manned facilities and the high cost. Such facilities are convenient for research and preliminary development of production processes and equipment, but production itself is best set up on special unmanned vehicles. The first designs of such vehicles have been produced—the Central Special Design Bureau's Nika-T (ZEMLYA I VSELENNAYA, 1992, No. 4, p. 18) and the S. A. Lavochkin NPO's Tekos. There is no doubt that, in the 21st century, vehicles that are of a more advanced nature will be created.

Space—Our Home

In the United States, which assumed the role of leader in the development of space after the breakup of the Soviet Union, the voices of the skeptics have begun to ring increasingly louder: there's no more Nikita Khrushchev chasing us, beating his shoe on the table and promising to bury us, so isn't it time for us to spend the taxpayers' money a little more carefully? (By a decision of the U.S. Congress, spending for the study and development of space was reduced in 1994, for the first time in 20 years.—*Ed.*) Spending for space is high, but the results are vague. The optimists retort that that's asking the question the wrong way. It should be asked differently: what might we miss if we begin to economize too much? Three hundred years ago, those who believed Columbus were the winners. Today, the expanses of space stand open to mankind. Of course, we have to pay for our success. But that's true in any new field, including the development of space. The assets that will be afforded mankind when he develops outer space will be immense. For that reason, the time has come to understand this: space activities are not just an episode in the history of mankind. Space activities are our fate.

Development of Reusable Air-Launched Booster Systems Urged

957Q0005 Moscow SEGODNYA in Russian 6 Oct 94 p 9

[Article by Mikhail Chernyshev, under the rubric "Thoughts": "Buran, Blackjack, or Something Totally New? Whatever the Stake, the Aircraft Designers Intend to Get Revenge From the Rocket Designers"]

[FBIS Translated Text] For more than a half a century, since perhaps the time of the "star dreamer" Fridrikh Tsander, an argument has been going between rocket designers and aircraft designers about which is the more economical way to explore space—with expendable rockets, or with reusable spaceplanes? The rocket designers have won so far. They are carrying most of the burden in

the exploration of near-Earth space and the study of the planets. The American Shuttles, the Soviet Buran, and the yet-to-be-completed Western European Hermes—reusable systems that appeared on the scene after the rockets—represent a whimsical combination of rocket and airplane.

In terms of economy, the reusable systems have not lived up to the hopes that people had for them. At one time, the creators of the American "shuttle craft" promised to reduce the cost of delivering a kilogram of payload to orbit to just about $200. Nothing of the sort has happened. Even with the most economical expendable rockets, the "going rate" is several thousand dollars per kilogram, and with the American "shuttle craft," the rates are considerably higher. Don't even mention Buran: huge amounts of money were spent on the development and construction of several craft, and those neglected "vessels" are sitting out in the far reaches of the steppes of Kazakhstan. And the spaceplane made a total of just one experiment flight, in pilotless mode. There probably won't be any other flights. It looks as if the Western European Hermes won't ever see the sky at all.

It took a whole 30 years to develop expendable boosters capable of lifting anything into space, says German Zagaynov, the director of TsAGI [Central Aerohydrodynamic Institute]. Another three decades were devoted to the creation of the gamut of rockets that cover the entire range of payloads that exist today: payloads that go from several hundred kilograms to hundreds of tons or more. Those boosters, based on today's concepts, are almost ideal in terms of design; series production has been perfected; and there's an infrastructure in place to service the launches. Competing with them in terms of economy is an almost hopeless affair. But specialists now are counting on systems with a so-called horizontal launch: when a spaceplane goes up into orbit by using a larger, carrier aircraft as a launch platform. In the opinion of designers from the United States, Russia, and other countries, such a plane can still find a niche and will perform operations in which it would be inefficient to use expendable boosters.

The response to such intentions has been varied. When the HOTOL project was announced in Britain in 1987, it got no support from the European Space Agency or the government itself. Only Rolls Royce saw fit to take a risk. The seeds of the call, nevertheless, were planted, and the romantics of aerospace found followers. Within two years, German specialists introduced the world community to the Saenger project. Today, similar projects exist in other countries, too. States such as Japan, China, and India, for example, are displaying a great deal of interest in spaceplanes.

The launch of a spaceplane into orbit from a carrier aircraft has a number of advantages over a rocket. The "launch pad" is not tied to any particular place, which means that many of the political restrictions often associated with space launches are removed and there's no need to set aside land for right of way, that is, expansive tracts of land along the flight trajectory of the booster on which spent rocket stages fall.

Everyone knows of the project that involves the use of the Mriya aircraft as a flying cosmodrome and that links three participants in cooperation—Ukraine, Russia, and Britain. There's less information available on the possibility of using the Tu-160 supersonic strategic bomber (called Blackjack by NATO) in a similar role. That airplane was originally created in response to a similar American aircraft, the B-1B, a cruise-missile platform. The dazzling white Blackjack has four engines and a wing geometry that is variable in flight. It flies at a speed that is a little more than twice the speed of sound. People regard it as the biggest military airplane every created.

If there is still only one Mriya aircraft to this day—Ukrainian aircraft builders will never finish the second—there are plenty of the Tu-160 bombers around. Using them as a flying cosmodrome or, if you will, the first stage of a booster requires only a minimal amount of reoutfitting of the airplane—essentially just removing the weapons and ammunition. The second stage would be an already separate reusable spaceplane. But even that two-stage profile could be of only temporary interest to the space program.

The future—in the opinion of Prof. Aleksandr Pukhov, one of the leading specialists at the Tupolev firm—is with systems such as the Tu-2000 single-stage-to-orbit aerospace plane. The takeoff weight of the craft is 70-90 tons, and its length is 60 meters. The spacecraft burns liquid hydrogen. There is a two-man crew. If the people on the ground want to set up normal freight traffic into space that is moderate in terms of cost and to handle applied, science-related, and (God save us, all it takes is one wise guy to start it, and the rest jump in—**Ed.**) military objectives, then they need to rely on that very "space horse."

In the past, when the issue of choosing the most efficient space transportation systems was being handled, an interdepartmental scientific-technical council was formed in the former USSR. Its decisions recorded unambiguously that the high road to space is a single-stage-to-orbit reusable aerospace plane. But any technical problem is solved with the means that are accessible at that stage of technological development. In the fifties, Sergey Korolev was able to launch a satellite with only a three-stage rocket. Today, we have, for example, the Mriya, which in essence can be the first recoverable booster stage; but then, as has already been said, there's the Blackjack, which is better in terms of the preliminary altitude of lift and the payload boost velocity. And then finally there's the ideal, as it were, single-stage-to-orbit Tu-2000.

We need to achieve not simply a 15-20 percent reduction in transportation expenses, says Prof. Pukhov, but changes that are more radical. And that can be done. Here's just one example. Right now, the American shuttle craft use an expendable fuel tank. It's a multilayer thermos that can withstand incredible temperature differentials. One square meter of the shell weighs 30 kilograms. The weight of the tank needs to be reduced twofold, and the tank has to be made so that it can be used, say, a hundred times. It's a difficult task, but doable. Only by doing those kinds of things can real economy be achieved. In the ideal, "reusable" means that the system has no expendable parts at all. Individual components such as, say, the chassis, could be replaced after 5-10 flights, but the airplane as a whole must be capable of making 100-150 flights into space. Servicing it requires fewer personnel than does servicing rockets, and

the need for erecting facilities such as assembly buildings and launch sites is eliminated.

Single-stage-to-orbit airplanes would best be used for placing small and medium-sized cargoes—6-10 tons—into relatively low orbits—400 km or under. Until recently, the greatest demand was for placing large communications satellites into geostationary orbit. But all of a sudden, there's also a need for small vehicles that circle at low altitudes. Hundreds of them are needed.

Mikhail Kazakov, lead designer at the Tupolev ANTK [not further expanded], feels that there are technical inventories that would make it possible to flesh out various kinds of boosters, but things depend less on technical possibilities than on money. We are talking about outlays of $2-3 billion. Of course, it would be better to do such a project in cooperation with, say, Germany, which, as has already been said, has the Saenger project, which is similar to ours. But each state has its own way of handling such problems. The United States, for example, doesn't want to share anything with anybody. It wants to have its own equipment exclusively and then sell it. But then, that's their right. But we, it seems, still should seek out partners. But mainly, with today's meager state financing, we should do at least the minimum experimental work on future spaceplanes, so that we won't be left standing by the side of the road.

Control in Problems of Increasing Disposable Energy and Safety of Boosters

957A0119A Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 11, Nov 94 pp 35-37

[Article by Yu. P. Portnov-Sokolov, doctor of technical sciences, professor; the first paragraph is an abstract; UDC 681.3:629.76]

[FBIS Translated Text] The principles and methods for increasing the principal energy parameters and safety of functioning of boosters with liquid-propellant rocket engines are examined.

The onboard complex for the control of boosters consists of systems which in contrast to systems for control of motion do not have even a remote prototype in automatic pilots or shipboard automatic rudder control systems. These are systems ensuring an increase in the principal energy parameters of a booster due to better use of the disposable fuel supplies with the most complete possible extraction of the energy which they contain. A gain is attained by choosing such a combination of continuous and discrete actions for control of fuel expenditure, operating modes of liquid-propellant engines, times of shutdown of engines and removal of mass which imparts to the booster by the terminal moment (end of active flight segment) the greatest velocity or affords the possibility of putting the maximum payload into a stipulated orbit. The gain attains 10...15% or more.

These points served as a basis for developing the concept of an increase in the energy parameters of boosters by control devices and methods [1].

Work on developing a control system of the described class was initiated due to the development by S. P. Korolev in the early 1950's of the first R-7 intercontinental and space missile when the booster designers came to the definite conclusion that without engine control it is not possible to "squeeze" a maximum flight range or lift from the rocket.

In order to achieve the selected control goal—synchronization of evacuation of the oxidant and fuel tanks in each of the booster units using a so-called packet scheme, as well as synchronization of fuel expenditure of all the lateral units with that of the central unit, it was necessary to change the ratio of expenditures and the total expenditure in each of the five principal engines of the bundle.

Here the physical essence of the effect of an increase in the energy parameters is that with synchronization of the evacuation of tanks by the time of shutdown of a liquid-propellant engine it is possible to reduce considerably the guaranteed fuel supplies isolated in the tanks for compensating for random perturbations and the fuel made available is used for increasing booster velocity.

The task of constructing the first fuel expenditure control system (SURT) of the R-7 booster required a very high scientific input and was very complex in design and engineering respects: priority studies of liquid-propellant engines as an object for control were carried out, its mathematical model was found, stability and transient processes in it were determined, rational coordinates for measurements and control were ascertained and methods for electronic modeling of liquid-propellant engines were proposed and realized. For the first time a mathematical model of the object was obtained in a SURT which included tanks, fuel system and liquid-propellant rocket engine; the first studies of thrust control systems and rocket fuel expenditure were made. These studies made it possible to ascertain the required parameters of the sensors regulating the actuating components and drives; the determined analytic parameters of liquid-propellant engines were confirmed experimentally and the requirements on the principal components of the system—the pressure sensor in the combustion chamber and servodrive—were included in the technical specifications for their development and were realized. Thus a pressure sensor was developed with an error not greater than +/-0.4%, as well as drives with high dynamic parameters operating successfully under conditions of installation on a liquid-propellant engine.

The basis of the principle for SURT operation is a comparison of the relative fuel supplies in the tanks and the ratio of the instantaneous expenditures of the components was measured for keeping limitations on the ratio. Control was accomplished by a change in the ratio of the expenditures of components and by variation of the total expenditure by the liquid-propellant engine. The initial information was used as a basis for writing a control algorithm.

The most complex task in the actual structural embodiment of the first system was a search for the principles for measuring fuel supplies in the tanks of a flying rocket and also the expenditure of its components. The problem was considerably complicated by the fact that the efficiency of the system was manifested only with its exceedingly high terminal accuracy (0.1...0.3%) and rigorous restrictions on the ratio.

The task of measuring fuel supplies proved to be so complex that its solution required drawing upon the resources of a number of academic and industrial organizations; a broad range of operating principles was examined: inductive, capacitive, ultrasonic, endovibrator, high- frequency, radioisotopic, pneumohydraulic, etc. As a result it was established that it is virtually impossible to construct a continuous sensor with the necessary measurement accuracy in the required range. A discrete measurement principle was selected which made it possible to obtain information on the mismatch of the evacuation programs for two tanks in the form of time intervals determined from signals from sensing elements positioned in the tanks. This measurement method, called the threshold-discrete method, made it possible to obtain a high accuracy in measuring the relative difference in the volumes of the components (to 0.07%), which was effectively favored by a special hydromechanical filter. The developed flow meters of the turbine type ensured an accuracy of 0.3...0.8%.

After constructing the SURT, successfully operating in rockets of the R- 7 family in thousands of launches, several generations of standard- produced SURT appeared for all large defense and space missiles produced in our country, up to and including the Energiya booster. In the development work of recent decades, oriented on onboard computers, the principles of prediction of the time of total exploitation of the fuel have been realized, which has made it possible to increase the energy gain. It was necessary to organize, on the basis of prediction results, in interaction with the system for the control of motion, a reduction of the zones of alienation for the regions of falling of the expended rocket fragments and thus reduce the ecologic losses in launches, especially in nonstandard situations.

The control algorithm was substantially reworked: it became resistant to failure, which increased control reliability. The algorithms written imparted to the systems and objects the properties of control flexibility, that is, the capacity to ensure functioning of the object in different modes, with impairments, with a possible change in the flight goal, etc.

As a result there was large-scale introduction of the SURT, which became an indispensable part of the boosters constructed in our country and which exhibited a high efficiency. For example, for the Proton booster, when launching a station of the Salyut class, the payload gain attains 2250 kg; for the Soyuz booster of the R-7 family it is 750 kg, etc.

Further development and generalization of work in the field of construction of the described systems, as well as such systems for control of the final state as systems for booster launching, rendezvous of spacecraft, soft landing, etc., predetermined the formulation and further development of the theory of terminal control systems as a special class of systems. In this class control is organized on the basis of an analysis of the prehistory of the control process, evaluation of perturbations and prediction of the anticipated miss (nonclosure of boundary conditions). A feedback is organized on the basis of the predicted miss, which most adequately corresponds to the principal objective of terminal control.

The theoretical results which were obtained can be divided into three groups of methods for the synthesis and analysis of terminal control systems [2]: 1) methods directed to an increase in control quality; 2) methods for improving control reliability; 3) methods reducing work input and increasing the reliability of computations when designing systems. While working out these methods a number of nontrivial principles were developed for constructing systems, as well as approaches for improving their parameters and research procedures. These include a threshold-discrete principle for programmed control, optimization of quantization intervals in pulsed systems, ideology of algorithmic resistance to failure, optimization of systems with restriction on structure (complexity), evaluation of limiting accuracy possibilities of systems, new statistical modeling methods, etc.

The methods taken together can be assigned to an individual section of control theory: the theory of onboard terminal control systems. The methods are based on active use of modern mathematical tools and make it possible to solve many practical problems in constructing and investigating systems of this class.

Next the problem of increasing safety by control methods and devices is considered.

The evolution of requirements on control systems has gone through a number of stages. First the dominant requirement was stability; then an increasingly greater role came to be played by the requirement of control quality, and after them—reliability control. Now, however, possibly as a result of a number of technogenic catastrophes, the safety requirement is becoming increasingly more pressing. The satisfaction of this requirement, in combination with the three preceding ones, means in essence a minimization, as a result of control, of the risk of appearance of emergency situations during functioning of the object.

During recent years the emphasis has turned to new approaches to an increase in the reliability of terminal control systems and development of elements of the theory of control systems with respect to the safety factor. Some of the results also are extended to systems for control of the nonterminal type.

Terminal control systems with a vector of perturbation of a high dimensionality were the object of investigation, as were linear multidimensional systems in which anomalous modes are possible due to failures in the apparatus or excessive perturbations and changes in configuration.

There are two principal aspects of the problem of investigation of anomalous modes in control systems with reconfiguration:

1) detection of anomalous parameters of the control process arising as a result of its transpiring in nonstandard situations (NS) and representation of the collected information in the form most suitable for subsequent use (identification, improved filtering, evaluation and prediction of state in real time, information compression, etc.);
2) search for the most adequate restructuring of the system for reducing the risk of unfavorable consequences of NS by means of imparting to the control

algorithm the properties of resistance to failure by rational methods for organizing control in terminal systems having impairments and by means of a built-in expert system, producing recommendations on change in strategy, modes and purposes for functioning of the control system.

The following principal results were obtained with respect to the first group of problems: a method for the effective compression of information on the process attained by a representation of the spectral portrait by a minimum number of parameters was developed; a method was proposed for two-level filtering of correlated noise, making it possible to parry the influence of the methodological errors of the simplified predictive model; a method was developed for evaluating the state and making a technical diagnosis of multidimensional control systems based on control of the position of the transfer function poles, increasing the reliability and accuracy of localization of the anomalous modes; a high- speed method was developed for evaluating random parameters based on conditional maximization of the a priori probability density function for all the random factors; applicable to the problem of predicting the final state of the terminal system, a correlation method was developed for evaluating a high-dimensionality (on the order of tens-hundreds) vector of perturbations.

The following results were obtained in the second group of problems: the methodological principles for the synthesis of an optimum strategy for escape from a NS ensuring minimization of the negative aftereffects (the method is oriented on the record in the built-in expert system and is adapted for operation in real time) were developed; a method was proposed for the synthesis of rational structures of control algorithms resistant to failure based on aggregation of the states of the system generated by failures into groups, combined with the possibility of using the same algorithm (such an approach makes it possible to increase the algorithmic reliability of the control system with an economical expenditure of computation resources); multilevel iterative schemes for numerical optimization and solution of equations applicable to problems in statistical optimization of parameters and on-line search for controlling parameters in NS were formulated; an algorithm was worked out for rapid search for a high-dimensional vector of control parameters in solution of problems with respect to the safety factor.

The results of these investigations are being realized both for increasing the safety of rocket-space technology objects and in a conversion plan: in the development of SURT for promising boosters; in improvement in systems for solving the coordinate problem for observation satellites; in development of new-generation launch complexes with increased reliability and safety; in development of a new strategy for the control of launching for increasing the safety of operation of boosters; in development of systems for automated analysis of in situ tests; in problems involved in preparation of algorithmic support for medical instruments and systems with a high accuracy and a long useful life; in problems of analysis of processes in market economics in the presence of destabilizing factors, etc.

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Plans, Programs of Polet Association Outlined

957Q0022 Moscow ROSSIYSKIYE VESTI in Russian 10 Nov 94 p 8

[Article by Vladimir Igolkinev, special correspondent for ROSSIYSKIYE VESTI, dateline Omsk: "New Strategy for 'Polet'"]

[FBIS text] The Polet Association is the only Russian rocket-space complex that independently showed its technologies and conversion programs at the air show in Fairnborough (Great Britain). Its participation in the show adjusted considerably its strategy for the association's entry into the world market.

That pertains primarily to the use for commercial purposes of the light-class rocket Kosmos, the world's cheapest and most reliable system for delivering various types of facilities weighing 300-1500 kg to orbit. We've been flying those rockets for almost a quarter of a century, and a multitude of satellites have been placed into near-Earth space with them. In the United States, it was only recently that a rocket of that class was tested. The launch ended in failure and costed the taxpayers $25 million. The road-tested Polet program is considerably cheaper.

A concrete result of the participation in the air show was the signing of two contracts with American and Swiss firms; preliminary negotiations with those firms had been going on for several months. U.S. and Swiss satellites will be placed in orbit from Russian launch facilities before the end of the year by rockets built in Omsk. That became possible after the COCOM system of bans was lifted by the West. So the road to "space" commerce is now open. Polet has already purchased from a Russian trade agency the license for the five-year rights to use the Kosmos rocket to launch domestic and foreign vehicles and for the sale of services involving the creation of low-orbit satellite communications systems. All that is the result of the steady personal contact between the two presidents—Yeltsin and Clinton—and especially the last visit of the Russian leader to the United States.

SS-25 Launches, Launch Contracts Described

957Q0024A Paris AIR & COSMOS/AVIATION INTERNATIONAL in French No 1495, 25 Nov 94 p 32

[Article by Christian Lardier: "One-Week Delay in Orion Launch"—first paragraph is AIR & COSMOS/AVIATION INTERNATIONAL introduction]

[FBIS Translated Text] Launch of the Orion-1 telecommunications satellite, scheduled for 21 November at Cape

Canaveral (Florida), has been postponed for a week due to a problem with the Atlas-2A launch vehicle...

The scheduled 21 November launch of the Atlas-2A from Cape Canaveral was first delayed for 24 hours because of bad weather in Florida, then for a week owing to a malfunction in the launch vehicle. Martin Marietta, builder of the Atlas and a rival of Arianespace, is supposed to launch the Orion-1 and Intelsat-704 satellites between now and the end of the year; in all, it has six Atlas-Centaur launching scheduled for 1994. Since 1990 the rocket has been made available in four versions. The Atlas-1 is an improved model of the old 162-ton Atlas-Centaur; Atlas-2 is a 185-ton stretch version for the US Air Force (MLV-2); Atlas-2A is its commercial variant (first launch on 9 June 1992, carrying the Intelsat-K); and Atlas-2AS, which weighs 233 tons, is an Atlas-2A flanked by four solid-fuel boosters (first launch on 15 December 1993, carrying Telstar-401). Of the 17 rockets launched since 1990 three have failed (1991, 1992, and 1993). Next year Martin Marietta plans 11 launches, while Arianespace is going to try for 13 (Cf. AIR & COSMOS No. 1491).

The 2,340-kg Orion-1 satellite built by Matra Marconi Space/British Aerospace at Stevenage (England) is based on the triaxially-stabilized Eurostar-2000 platform. It uses solar panels built by MBB (Germany) that deliver 2.8 to 3.4 kilowatts of power, batteries built by Eagle Picher (United States), and Ku-band repeaters (six 36-megahertz channels and 28 54-megahertz channels) built by Japan's NEC. For the first time, the payload will include semiconductor repeaters in the Ku band. Special 2.3-meter diameter antennas have been developed for the satellite, to give the antenna cluster full coverage of earth contours. Made of a composite material, ultralight Kevlar, these are the first antennas in Europe to utilize a laser-based dual-coating technology. The first satellite will be placed in orbit at 37.5° W., while the second (scheduled for launch in 1996) will go to 47° W. They will be competing against Intelsat and PamAmSat in the United States, as well as Intelsat, Eutelsat, and Astra in Europe. The next Ku-band satellites to be launched to provide coverage of West Europe are Astra 1-D on 1 December (Ariane), Orion-1 on 28 November (Atlas), Intelsat-706 on 15 February 1995 (Ariane), Intelsat-705 in April 1995 (Atlas), and Astra 1-E in June 1995 (Ariane). As of 30 June 1994, there were 416 Ku-band repeaters in orbit above this region of the world.

SS-25 Launches

Russian Strategic Forces in the last 3 months have launched a series of SS-25 Topol missiles. Two missiles were launched from the Plesetsk cosmodrome, on 23 September and 10 November respectively. On 22 June, President Yeltsin attended the launching of an SS-25 at Plesetsk, as well as the launch of a ballistic missile from a nuclear submarine in the Barents Sea and a long-range cruise missile. According to Lieutenant General Yuri Juravlev of the strategic forces, the SS-25 is going to become the primary vector of the nuclear arsenal and will also be utilized as a satellite launcher (Start). The four-stage Start carried its first satellite into orbit on 25 March 1993. Its next launch—carrying a satellite of the Teploteknik Institute and NPO Elas—is scheduled for December 1994.

Commercializing Start

Contacts were made with South Africa regarding a possible launch of the Greensat satellite in 1995, but the South Africans abandoned the program. The Norwegians and Swedes had considered launching Start from the base at Andoya, in Norway, but the price proposed by the Russians was too high.

The U.S. firm CTA Inc. has negotiated 14 Start launches from the Kodiak Island base in Alaska in late 1995-early 1996. Also, Cosmos and Start rockets are in competition for the contract with OHB System (Germany) to launch Safir satellites. And Israel's Technion University, which had planned to launch its Techsat-1 satellite (alias Gurwin) with Ressource 01 No. 4 on a Zenith rocket, has just signed the contract for a 28 March 1995 launch of a five-stage Start-1 rocket. Although this mobile launcher is a mature and low-cost product ($6-8 million), it has not been as successful as the builder, Center Complex, had hoped.

Plans for Manned Flight to Mars Outlined

957A0074A Moscow ZEMLYA I VSELENNAYA in Russian No 6, Nov-Dec 94 pp 22-32

[Article by S. P. Umanskiy: "Manned Flights to Mars"; the first two paragraphs are an introduction]

[FBIS Translated Text] The world's first artificial satellite was put into orbit on 4 October 1957. During the years which have elapsed (and already the first decades!) launches of satellites and automatic interplanetary stations have become routine. Even manned flights into space have become commonplace. The order of the day is implementation of new audacious projects: new flights of automatic vehicles to Mars, establishing lunar bases, manned flights to Mars...

We publish a part of a chapter devoted to future manned flights to Mars from the book entitled "Kosmicheskiye orbity" (Space Orbits), by S. P. Umanskiy, in preparation for publication by the Prosveshcheniye Publishing House.

Power-Propulsion Units for Martian Expedition

The transition of the problem of a manned expedition to Mars from the realm of ideas close to fantasy to the realm of scientific-engineering development work took place in Russia in the mid-1960's. Already at that time the principal problems which had to be solved for its successful implementation were outlined. Among the complex problems involved in a Martian manned expedition one of the most important (which has remained so to this day) is the power-propulsion unit to be used. It is understandable that liquid-propellant rocket engines (LPRE), even though in theory they could ensure a Martian flight, could be employed only with unacceptable initial masses of the interplanetary ship and a great number of launches would be required for its assembly in circumterrestrial orbit. Even the first analysis, made in the late 1950's, indicated that a considerable reduction in its launch mass could be attained by using nuclear energy in the power-propulsion units. Here three directions were outlined:

A nuclear rocket engine (NRE) with a solid-phase reactor,

A nuclear rocket engine (NRE) with a gas-phase reactor,

An electronuclear rocket engine (ENRE).

Research and preliminary engineering design development work began at several scientific research institutes: Thermal Processes Scientific Research Institute (NII TP), Atomic Energy Institute, Physical Energy Institute, NPO Energiya, Khimavtomatika Design Bureau and NPO Energomash. This work was supported by M. V. Keldysh, S. P. Korolev and I. V. Kurchatov. It was possible to obtain financial assistance from the government. An experimental solid-phase nuclear reactor (working medium—liquid hydrogen with some admixture) with a specific thrust 9100-9300 m/s was developed.

Research on a NRE with a gas-phase reactor indicated that the specific thrust may attain 20 000 m/s, but the realization of such a scheme involved great technical difficulties.

One of the problems in the way of use of NRE is the need for prolonged (not less than a year) storage of the working medium (liquid hydrogen). The fact is that special refrigeration equipment is needed which requires a power of about 100-150 kW.

An operating reactor is a powerful source of neutron and gamma radiation which without the adoption of special protective measures may result in inadmissible heating of the working medium (in the tanks), destruction of the ship's structure and radiation injury to the crew and passengers. In order to ensure radiation safety on flightcraft with NRE there must be special shielding and partitions made from materials absorbing radiation (lead, cadmium, gadolinium). But this inevitably increases spaceship mass.

Electric rocket engines (ERE), although they are characterized by a great specific thrust (up to 70-100 km/s), are low-thrust engines (0.1-1 N). ERE thrust is created using the electric energy generated by a solar cell assembly or a nuclear power plant. The use of ERE as sustainer engines is possible when constructing large units (linkups) consisting of a large number of engines.

Ensuring Radiation Safety

Beyond the limits of the Earth's atmosphere the constantly prevalent factors will be solar radiation (from the disturbed sun!) and galactic cosmic radiation (GCR). For example, GCR has a great intensity and passes through the ship's skin. The irradiation dose received in this way is about 0.2 rem/day. This is a relatively small quantity, but if an expedition to Mars lasts 2 years the received irradiation dose will be 140 rem, which is more than double the admissible level. Accordingly, the flight duration must be shortened as much as possible and a radiation refuge (or electrostatic protection) must be devised for the ship.

The building of a radiation refuge which could even temporarily hold 3-5 persons would involve a considerable increase in the ship's weight. The electrostatic shielding method today seems fantastic, but in theory a positively charged envelope could serve as shielding of such a nature. Such protection would ward off any positively charged particles, but it is totally ineffective against electrons, which, being drawn to it, will begin to be continuously accelerated. It would be possible to position a second envelope, charged negatively. Something similar to a double hull surrounding the ship would be the result. Finally, for ship protection it would be possible to attempt use not only of an electrostatic, but also a magnetic field.

Other effective means for ensuring radiation safety during a flight to Mars also might be use of pharmacological prophylaxis, rigorous calculation and regulation of the irradiation doses of each crew member, diagnosis of the condition of the cosmonauts by means of appropriate examination systems, and finally, use of means for additional local protection.

Cycling of Matter on Ship

One of the principal problems on a Martian expedition will inevitably be that of a fully satisfactory habitable medium in the ship, its adequacy for the long-term human biological needs. The changeover from flights in circumterrestrial orbits to interplanetary flights will require a qualitatively new approach to the understanding of the conditions for man's prolonged existence in an artificially created medium. Beyond the Earth there is only one way to create an analogue of the natural medium—use of physicochemical processes and natural biological mechanisms. Then an artificial environment is formed due to the combined activity of plants, animals, microorganisms and physicochemical transformations. Reference is to a closed ecoengineering system which includes man.

Various models of systems based on physicochemical processes, the activity of unicellular algae, higher plants and microorganisms have already been developed and investigated. In such models there is regeneration of up to 90-98% of the matter consumed by man. For flights to Mars it is scarcely feasible to propose a full-scale biological system capable of meeting all human needs. With a flight duration of 1-2 years there is no need for such a system and it will scarcely be profitable. However, it is impossible to rely completely on a physicochemical regeneration system for which individual technologies have been developed for obtaining oxygen and water from the products of man's vital functions. It is now advantageous with respect to weight, size and energy characteristics, but it does not provide a biologically fully adequate environment for man's habitation. Combined systems, including both physicochemical and biological processes, may be the most promising here.

A number of regenerative life support systems (LSS) were tested in the USSR in 1967-1968. Three subjects lived and worked in a pressurized surface spaceship mock-up over a period of a year. They used systems for the regeneration of water from a condensate of atmospheric moisture, urine, sanitary-hygienic and kitchen waste water, systems for atmospheric regeneration, utilization of carbon dioxide and electrolytic recovery of oxygen from water. A vitamin greenhouse was included in the LSS complex.

The LSS carried on the Mir station contains an apparatus for obtaining drinking water extracted from a condensate of atmospheric moisture. Since 1990, after docking of the Kvant-2 module, a system for obtaining water from urine has been functioning aboard the station. Electrolysis decomposes the water into oxygen and hydrogen. The

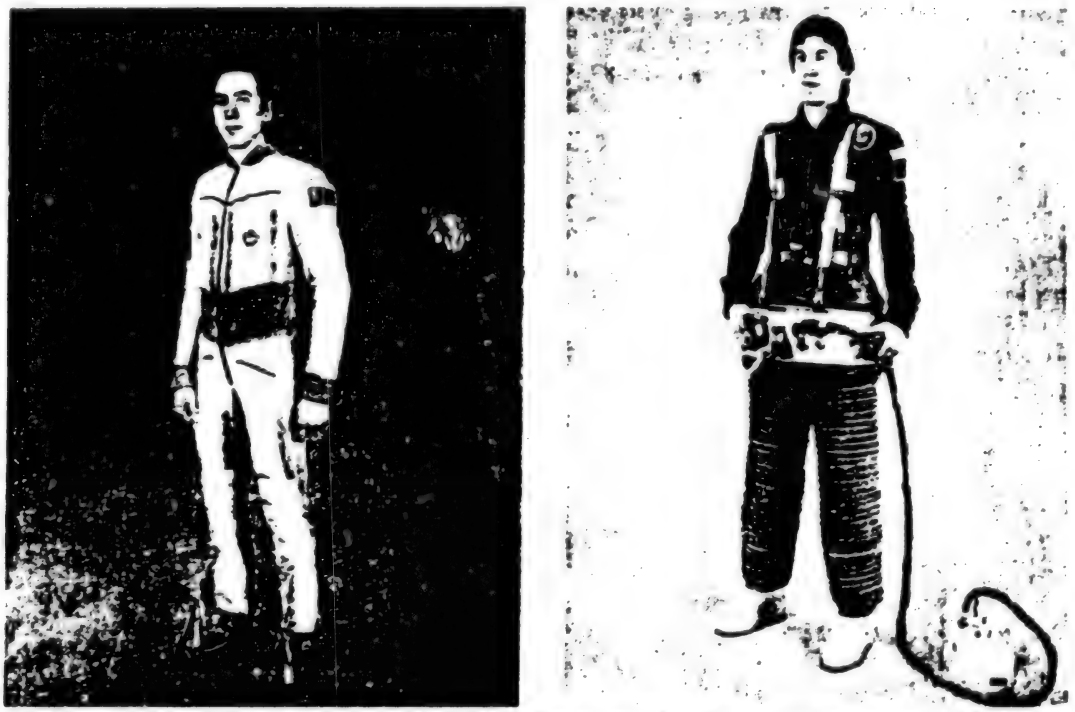


Figure on left: Pingvin-3 g-suit. Beneath the suit envelope there are rubber plaits (shock absorbers) which impart a load to the human skeletal-muscular system. Figure on right: Chibis prophylactic vacuum suit—an effective means for preventing disorders of the cardiovascular system during return to terrestrial conditions after prolonged presence in space.

required composition of the station atmosphere is ensured by the absorption of carbon dioxide and microimpurities. The daily food ration is calculated at approximately 3000 Cal per person. With a mass of about 1500 g it is made up predominantly of sublimated foods.

Aboard a Martian ship it seems feasible to use a similar LSS complex, supplementing it with a system for the utilization of carbon dioxide (concentration and subsequent reduction to methane and water or carbon and water). In addition, in the LSS complex it is desirable to include a greenhouse whose principal function would be psychological support and partial supply of vitamins to the crew (the greenhouse area would be approximately 15 m^2 per person.

Weightlessness or Artificial Gravity?

Space medicine has accumulated a significant amount of knowledge concerning the influence of weightlessness on the human body. More than 260 persons have already made space flights of different duration. Seven cosmonauts maintained a space watch for more than 200 days and Yuriy Romanenko spent a total of 430 days in space.

The system for the prevention of an unfavorable impact of weightlessness on the body developed by specialists in our country enables cosmonauts to live and work rather successfully even during the most prolonged flights.

Cosmonauts and astronauts usually are for flight to Mars in a state of weightlessness. Physicians, however, are for the creation of artificial gravity aboard a spaceship. Science must further accumulate necessary material in order to make the choice.

The matter of the number of crew members, to be sure, is important. It will be determined primarily by the design features of the technical systems ensuring flight and by the program for scientific work in flight and on the Martian surface. It is the opinion of some psychologists that it would be better that the crew be made up only of males (6-8 men). The crew should include persons in the age category 35-45 years, that is, specialists having professional and life experience, and, of course, experience in spaceflight. It is mandatory that the ship carry a highly qualified physician having good training in the fields of therapy, surgery, psychotherapy and psychology.

Prolonged Spaceflight

The successful solution of psychological problems also will play an important role in supporting a Martian expedition. In particular, there must be a psychological readiness of man for execution of a flight which inevitably involves a definite degree of risk. It will of course be of great importance to have earlier experience, as well as a knowledge of those circumstances which man may encounter on a flight to Mars. An exceedingly important point is the instilling of absolute confidence in equipment, assurance of the faultless operation of all its systems or the possibility of carrying out any repair work by themselves.

Specifications for Engine and Shipboard Power Plant

Specifications	Russia	United States
1. Duration of Earth-Mars-Earth expedition	up to 1 year	up to 1.3 year
2. Reliability of engine-power plant	more than 0.995	more than 0.995
3. Parameters for propulsion mode:		
thrust, kN	200	333
specific thrust, km/s	up to 9.5	up to 9.25
number of in-flight firings	more than 11	more than 10
4. Parameters for power mode:		
electric power, kW	50...100	20
in-flight operating time, years	up to 1.0	up to 1.3
5. Ratio of thrust to engine mass	3	4

According to preliminary development work the thrust of an individual engine is set at the level 68.6 kN (7 tons), number of engines in linkup 3-4.

During the course of the entire flight the cosmonauts looking into the abyss of space will see the very same picture. Through some ports in the bluish-black sky they will see only bright nontwinkling stars, but through others the blinding fiery disk of the nonsetting sun. And despite the fact that the ship is moving at an enormous velocity, for the cosmonauts everything will seem fixed, as if frozen in place.

The crew members will have a singular daily schedule: 4 hours—operational work, 4 hours—routine work, 4 hours—active rest and 4 hours—sleep. During the time of active rest the crew members will work out on special trainers, eat, read, listen to music, look at movies, conduct television transmissions with the Earth, analyze scientific material, etc. The daily schedule provides that all the cosmonauts on duty (or most of them) will simultaneously be seated at a table. Prolonged space flight is a very serious test of the human psyche and it can be withstood only by persons strong in spirit, those filled with enthusiasm for life, those highly dedicated to their work and psychologically compatible.

Martian Ship Using Nuclear Rocket Engine (NRE)[1]

A preliminary analysis of the efficiency of use of different types of rocket engines for a Martian ship was made at the Thermal Processes Scientific Research Institute (NII TP) in the 1960's on the initiative of Academician M. V. Keldysh. Preference was given to a power-propulsion unit based on a solid-phase reactor. Then the emphasis was placed on developing a fuel element containing uranium which during fission releases heat and heats the flowing hydrogen. With a heating temperature of 3000 K the hydrogen creates a specific thrust of 9.50 km/s, which is twice as great as for liquid-propellant rocket engines. In our country fuel elements have been fabricated from a mixture of uranium carbide and refractory carbides (zirconium and niobium carbides, but in the future the use of tantalum carbides also is possible).

In the 1970's efforts were concentrated on developing a fuel element assembly which consisted of a set of fuel elements, support unit and strong housing. Special test reactors were developed for surface perfecting and finalization of the fuel element assemblies.

In the 1980's a prototype NRE reactor was developed on the basis of the already developed fuel element assemblies.

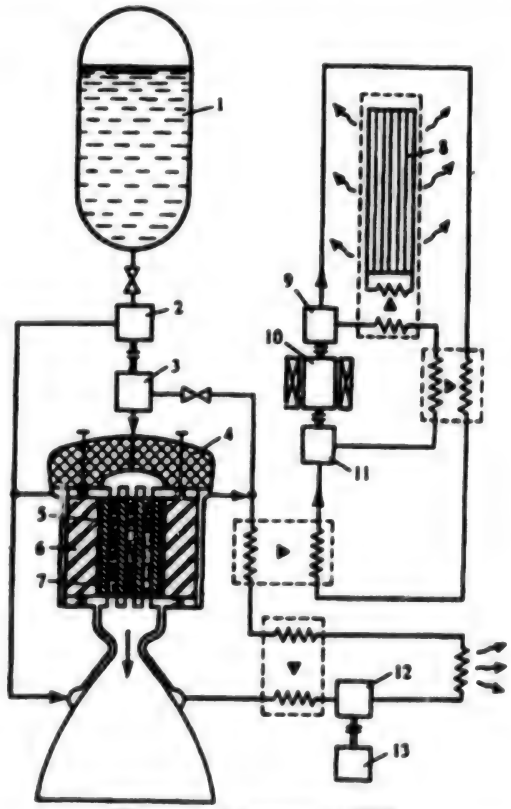
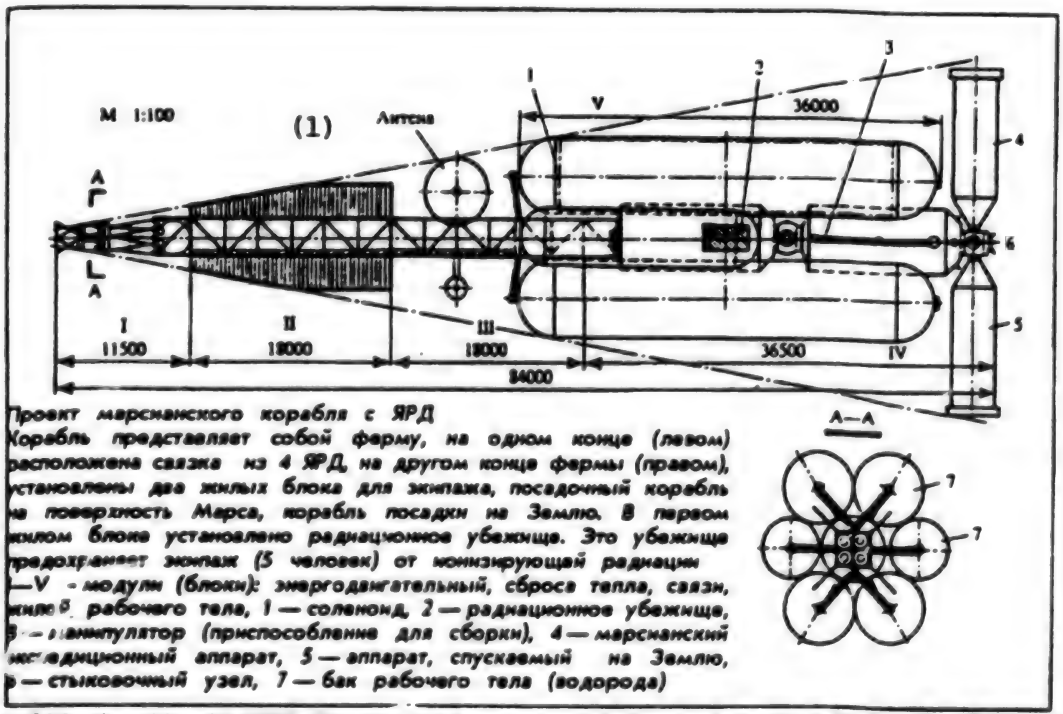


Diagram of two-mode NRE.

Key: 1. container 2. pump 3, 11. turbine 4. radiation shielding 5. fuel cells 6. drums 7. moderator 8. cooling radiator 9. compressor 10. generator 12. fan 13. motor

Principal Specifications of Nuclear Power Plant

Power plant scheme	**Linkup of 3-4 modules**
Nuclear fuel	Solid solution of uranium, niobium, zirconium carbides
Propulsion mode	
Rocket thrust, kN	200
Working medium	Hydrogen
Thermal power, MW	1200
Total operating time, hours	5
Specific thrust, km/s	8-9
Electric power, kW	200
Working medium expenditure, kg/s	22-25
Temperature of working medium at output, °C	2400-2700
Power mode	
Working medium	Xe and He mixture (1-3%)
Power conversion system	Brayton cycle
Electric power, kW	50-200
Maximum temperature of working medium, °C	900
Area of cooling radiator, m^2	600
Total mass of nuclear power plant, tons	50-70



Проект марсианского корабля с ЯРД
Корабль представляет собой ферму, на одном конце (левом) расположена связка из 4 ЯРД, на другом конце фермы (правом), установлены два жилых блока для экипажа, посадочный корабль на поверхность Марса, корабль посадки на Землю. В первом жилом блоке установлено радиационное убежище. Это убежище предохраняет экипаж (5 человек) от ионизирующей радиации
I—V - модули (блоки): энергодвигательный, сброса тепла, связи, жилой, рабочего тела, 1 — соленоид, 2 — радиационное убежище, 3 — манипулятор (приспособление для сборки), 4 — марсианский экспедиционный аппарат, 5 — аппарат, спускаемый на Землю, 6 — стыковочный узел, 7 — бак рабочего тела (водорода)

Design of Martian ship with NRE. The ship is a beam on one of whose ends (at the left) there is a linkup of 4 NRE, whereas at the other end of the beam (at the right) there are two living units for the crew, module for landing on the Martian surface and ship for landing on the Earth. The radiation refuge is located in the first living unit. This refuge safeguards the crew (5 men) against ionizing radiation. I-V—modules (units): power-propulsion, heat discharge, communication, living, working medium. 1) solenoid, 2) radiation refuge, 3) manipulator (device used in assembly work), 4) Martian expeditionary vehicle, 5) vehicle launched to Earth, 6) docking unit, 7) working medium (hydrogen) tank.
Key: 1. Antenna

A special feature of the selected NRE scheme was provision for two-mode operation (propulsion and power). The latter supplies electric power to different shipboard users, including the system for long-term storage of cryogenic components aboard and the system for magnetic shielding of the crew against galactic radiation.

Among the different power cycles for the conversion of reactor thermal energy into electricity the choice made was for a closed gas turbine cycle (Brayton cycle). It, operating on an inert gas (xenon or xenon-helium mixture), has an increased reliability and high efficiency (efficiency 20-30%).

The third figure in this article shows that the choice was a two-circuit power mode scheme: a first (reactor) circuit with a hydrogen working medium and a second (gas turbine) circuit with an inert working medium. Such a scheme also makes it possible to solve the cooling problem. The fact is that after shutdown of a nuclear power plant heat release, caused by the decay of fission products (uranium-235), continues. Accordingly, after shutdown it must be cooled for several hours (by means of the first power mode circuit).

This development work in our country relies on a heterogeneous reactor scheme in which the neutron moderator material and the materials containing uranium are separately present in the active zone. Such a scheme has a number of advantages. These include the possibility of using the most efficient moderator based on zirconium hydride (which reduces the size of the NRE); convenience in perfecting and finalization of active zone elements, and most importantly, the fuel element assembly containing uranium which heats the hydrogen to a temperature of 3000 K. In such a scheme the fuel element assembly is a self-contained integral unit which can be tested and perfected in other less expensive reactors.

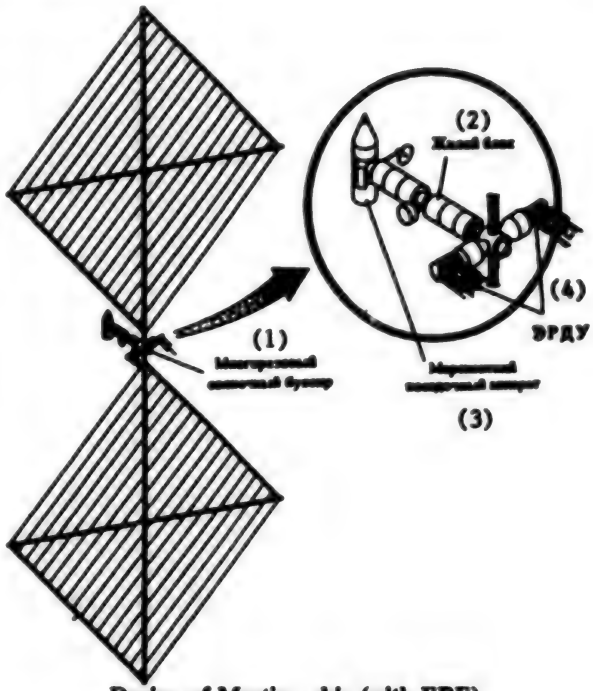
The use of large quantities of liquid hydrogen requires special cooling apparatus which must be supplied an electric current of about 100-150 kW. With allowance for the necessary power (about 50 kW) the total power consumption level will be 150-200 kW.

Much attention is being devoted to development of crew shielding against the ionizing radiation of a NRE, as well as study of nonstandard and emergency situations which might arise when carrying out a manned expedition.

Martian Ship With ERE (NPO Energiya Project)

The ship consists of the following principal parts: Martian orbital vehicle, expeditionary vehicle, vehicle for return to Earth, electric rocket engines unit and solar cell assemblies.

The Martian orbital vehicle is the core unit of the expeditionary complex. The crew lives and works in it during the entire expedition. The vehicle is designed as a cylinder 4.1 m in diameter divided into three (living, transfer and work) compartments. In the living compartment there are cabins for each crew member, a common living area and rest zone. A greenhouse, food preparation facilities and radiation refuge also are situated here. The mass of food products is 5500 kg and that of the emergency food reserves is 1000 kg. In the radiation refuge water is used as the shielding material and there are different kinds of equipment. Instrumentation and the central control station are in the work compartment.



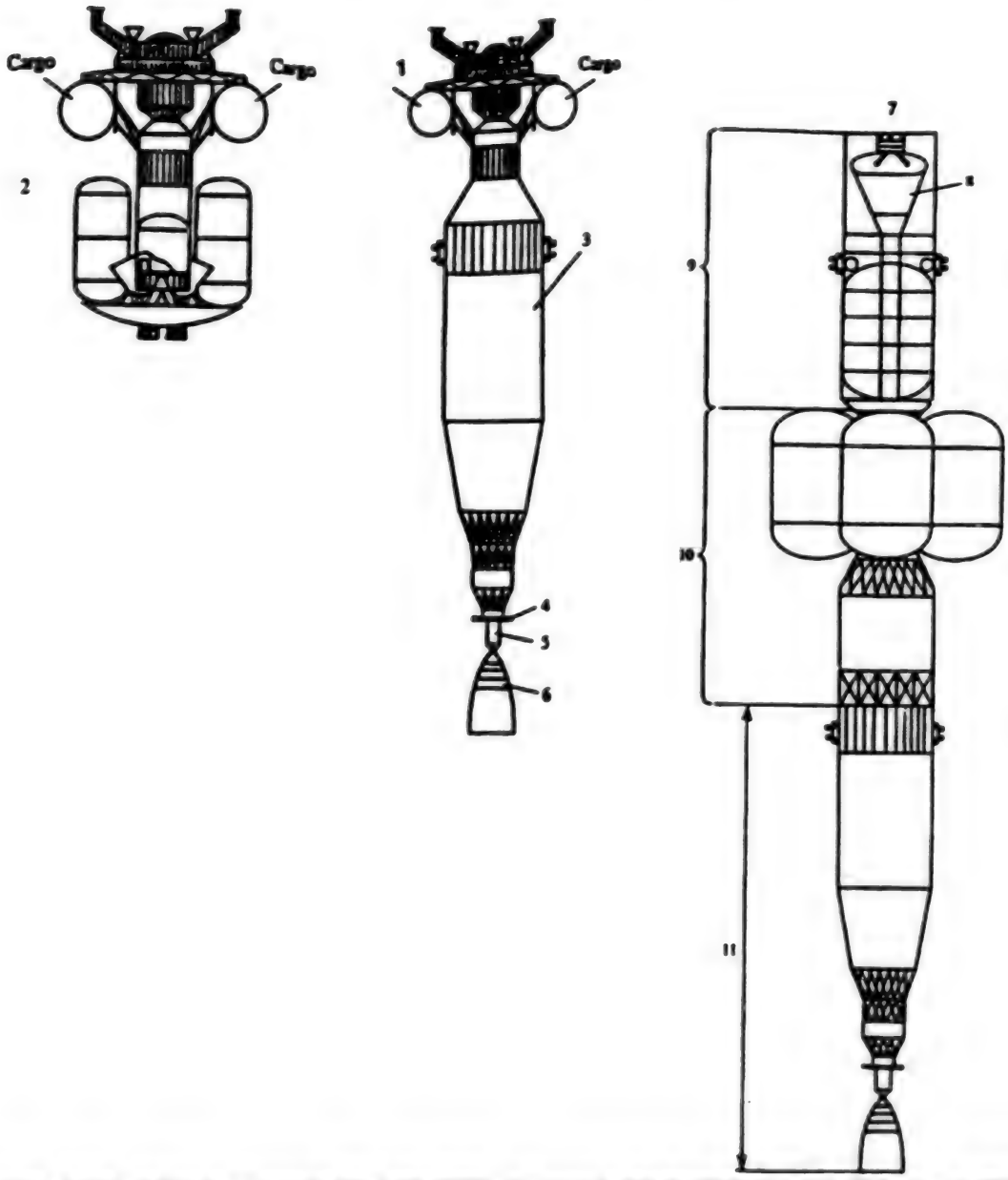
Design of Martian ship (with ERE).

KEY: 1. Reuseable solar tug 2. Living module 3. Martian landing module 4. ERE

The expeditionary vehicle has been worked out in two variants: in the form of a cylindrical compartment with a conical bow and in a conical pear-shaped configuration. Both variants ensure controllable descent in the Martian atmosphere with an aerodynamic quality 0.3-0.5. The existing propulsion unit makes it possible to land on the Martian surface at velocities up to about 2 m/s. The expeditionary vehicle is sectionalized and consists of the Martian living compartment (forward cone), landing propulsion unit compartment, returnable module compartment and tail compartment with the braking engine.

Principal Specifications of Martian Ship With ERE

Number of crew members	4
Number of crew members making landing on Mars	2
Number of launches of Energiya booster for organizing expedition	5
Total mass of ship, tons	355
Mass of Martian orbital vehicle, tons	80
Mass of expeditionary vehicle, tons	60
Mass of vehicle for return to Earth, tons	10
Mass of ERE structure, tons	40
Mass of working medium (xenon), tons	165
Total electric power of ERE, MW (at Earth)	7.5x2
Total duration of expedition, days	716
Time of presence on Mars, days	7



American design of Martian manned ship (with NRE). 1) manned ship for flight to moon, 2) lunar expeditionary module, 3) tank for liquid oxygen (127.5 tons), 4) radiation shielding, 5) NRE, 6) nozzle, 7) Martian manned ship, 8) Martian expeditionary module, 9) payload, 10) tanks, 11) module used for flight to moon.

The useful life of the systems is rated for a weeklong presence on the Martian surface and 24 hours in a Martian satellite orbit.

The solar cell assembly consists of two identical panels measuring 200 x 200 m, formed by diagonal beams. The ends of the beams are connected by cables to which photovoltaic cells are attached. The thin-film photovoltaic cells for converting solar energy into electric energy proposed by the NPO Energiya are of unquestionable interest.

The removal of the solar cell assemblies and their in-flight replacement is possible. Ultrathin (50 μm or less) and ultralight solar photovoltaic cells (from high-resistance silicon) are now being developed; these have a low specific mass (0.2 kg/m^2) and a relatively high factor for conversion of solar energy into electric power (150-200 W/m^2).

The life support system includes a complex of physicochemical and biological processes. The following initial specifications (man/day) were adopted when determining the LSS

parameters: O_2 supply—600 liters, CO_2 elimination—480 liters, water supply—2.5 kg, food supply (from reserves)—1.5 kg, plant food—0.4-0.5 kg, water expended from reserves—0.5 kg. Greenhouse area—15 m^2/man, mass 500 kg. The greenhouse is necessary for supplying the crew with vitamins and in part with products of vegetable origin, but also for creating psychological comfort. The mass of the LSS is 26 tons, including food products 5.5 tons.

The flight scheme provides for maneuvering in the Earth's gravity field. In the initial flight segment, to an altitude of 40 000 km, the engines operate with a doubled thrust (with a specific thrust of 35 000 m/s), which makes it possible to traverse this segment dangerous with respect to the radiation level in only 29 days. With a total flight duration of 716 days propulsion near the Earth will require 100 days, the Earth- Mars flight—270 days, braking near Mars—38 days, presence in a Martian working orbit—30 days, propulsion near Mars—28 days, flight to the Earth—250 days. The return module enters the Earth's atmosphere at a velocity 13.5 km/s.

The first units to be put into an earth satellite orbit would be the orbital vehicle and the ship for return to the Earth. The next units would be the Martian landing module and the solar cell assemblies, ERE and working medium—a total of 5 launches.

American Project for Martian Manned Ship With NRE

In 1989 the president of the United States approved a program for exploration of the Moon and Mars—SEI (Space Exploration Initiative). A "return to the moon" is regarded as the first stage in a program ensuring practical checking of the Martian ship systems. Even today it is clear that the moon may be of substantial assistance to the Earth in solution of many of its problems. What this amounts to is that in the not distant future some harmful processes having a destructive effect on ecologic conditions will be carried beyond the limits of the planet and, in particular, to the moon.

The following arguments are cited for such an organization of the Moon-Mars program:

—the technical solutions developed for exploring the moon are used for Mars;

—fuel produced at a lunar base is used for the manned expedition to Mars;

—fuel produced on Mars using the technology developed for the moon can be used for return to the Earth.

American specialists assert that all this will considerably reduce expenditures in implementing a manned expedition to Mars and will favor industrial exploitation of lunar resources.

According to the most optimistic predictions a lunar flight might be made in 1999 and a flight to Mars early in the 21st century, with a Martian base being established in 2022. The duration of the expedition would be 406 days—including flight to Mars 147 days, presence on Mars 30 days and flight to the Earth 229 days. The mass of the lunar ship (in circumterrestrial orbit) would be 218 tons and the mass of the Martian ship 638-668 tons.

And Nevertheless—Why Mars?

It is now difficult to visualize those discoveries which may be made as a result of the exploration of Mars. For example, it is possible to fantasize that traces of a civilization greatly outstripping us in its development, but which due to unknown circumstances was forced to resettle to another solar system, will be discovered. And suppose that their emissaries already long-long ago visited the Earth, but the conditions here seemed unacceptable to them and they flew off, accompanied by the roar of the shaggy creatures which had just begun to stand on their hind legs?

We recall the expedition of Columbus. Its driving force was a thirst for enrichment, but the result was the discovery of a new unknown continent. But possibly Mars can wait a bit; can we not wait several years for better times? I don't think so. After the standoff existing between the great powers Mars can and must become a symbol of cooperation in space. The very formulation of the problem of peaceful cooperation of states (as an alternative to the arms race!) is an important stimulus for the mobilization of public opinion. Whereas the Apollo program cost the United States 25 billion dollars, manned flight to Mars will involve expenditures three times as great. To be sure, 75 billion dollars is a lot of money, but if it is compared with the SDI program (more than a trillion dollars), this, to be sure, is not very much.

Footnote

1. This section was written by V. F. Semenov.

Russian Mars Robot Tested in France

957A0068A Paris AIR & COSMOS/AVIATION INTERNATIONAL in French No 1499, 23 Dec 94 p 62

[Unsigned article: "Trials of Martian Robot 'Marsokhod' at Toulouse. The Russian 'Rover' of the Mars-98 Mission Will Have an Autonomous French Navigation System"]

[FBIS Translated Text] The Russian Marsokhod autonomous planetary exploration vehicle has begun its trials on the grounds of the Group for Studies of Mobile Space Robotics (Geroms) established by the CNES, the CNRS-LAAS and ONERACERT at Toulouse. The machine, which is to be launched on the Mars-98 probe, was developed by the Babakin Center of the NPO Lavochkin at Khimki near Moscow over the course of many years. In its original variant it was telecontrolled, in other words, it was to receive its directions for forward movement from the Earth. Its safety is ensured by a great number of devices (inclinometer, instrument for measuring the run along the routes, etc.). These measures will provide assurance of an emergency stop of the vehicle. In order to increase assurance of detecting obstacles at a distance and ensure its autonomy France has proposed furnishing cameras, as well as algorithms for stereoscopic vision and navigation, in order to reconstruct the terrain and generate trajectories. These algorithms are compatible with the very limited onboard resources with respect to computation and memory capabilities. The stereovision equipment and its command electronics are to be furnished by the CNES

Space Astronomy Laboratory (Marseilles), whereas the onboard computer will come from the KFKI Institute in Budapest (Hungary).

The trials were begun on 15 December on the Geroms grounds, which consists of a "terrestrial" zone of 3000 m^2, a "lunar" zone of 2000 m^2 and a Martian zone of 600 m^2. The Russian rover has already undergone numerous trials on Kamchatka (in Russia) and in the Mojave Desert (in the United States). The McDonnell Douglas Company, on an equal footing with the NPO Lavochkin, is developing a Martian rover equipped with American telecommunications and avionics equipment. The six-wheel vehicular chassis is to be furnished by the TransMach All-Russian Scientific Research Institute in St. Petersburg. The scientific payload, 17.5 kg, still has not been determined by the Space Research Institute in Moscow, other than the system for taking samples. The experiments proposed by the international community include use of a gas-phase chromatograph, gamma, alpha X and neutron spectrometers, a Mossbauer spectrometer and an electromagnetic sounding instrument. The data are to be transmitted to an orbiter. Russia is studying a system for direct transmission from the Martian rover to the Earth.

On its part the CNES, together with Aerospatiale, Alcatel Espace and Sagem, is studying the VAP (Planetary Autonomous Vehicle) with an eye to a Martian mission in 2003. The technological draft for this program, the autonomous display of the mobile robotics for space exploration (IARES), is in the course of testing at Geroms. The CNES, moreover, has been entrusted the task of preparing the Adam robot of Framatome, Matra and the Laboratory for Analysis of Architecture of Systems (LAAS) of the CNRS for future planetary missions.

Implications of Jupiter Comet Collision Discussed

957A0121A Novosibirsk VECHERNIY NOVOSIBIRSK in Russian 13 Jan 95 p 6

[Interview between Yuriy Marchenko, scientific secretary, International Institute of Space Anthropoecology, and Dmitriy Serdtsev, VECHERNIY NOVOSIBIRSK correspondent: "Collision of Points of View Against Background of Jupiter. A New Institute, the International Institute of Space Anthropoecology, Is Working on This Question"; the first two paragraphs are an introduction; the last paragraph is a commentary]

[FBIS Translated Text] We also feel that in space there are other dimensions about which we know nothing. During the past year a major international experiment was carried out for confirming the reality of superdistant contacts.

The International Institute of Space Anthropoecology (MIKA) was organized last year in Novosibirsk. Yuriy Marchenko, candidate of medical sciences, scientific secretary of the MIKA, tells about the first results of its activity.

Serdtsev: Yuriy Yuryevich, why was the institute established?

Marchenko: We, and I have in mind especially a group of specialists of the Institute of General Pathology and Ecology of Man of the Siberian Department of the Academy of Medical Sciences, were closely within the framework of the traditional concepts of Academy science: living matter is possible only in nucleoprotein form; we people are the only reasonable beings in the universe; space is three-dimensional....

Such processes transpire and such phenomena occur in the surrounding universe which do not fit into existing concepts concerning space, distances and the reserves of the human body. An analysis of these facts led us to an understanding that life also evidently exists in a 'field' form.

Serdtsev: What does that mean?

Marchenko: It goes without saying that the word 'field' does not refer to sectors of land, but a field as a physical category. We hope to obtain proof that this region of organized space is permeated by definite interactions with an information content. We also feel that in space there are other dimensions about which we know nothing. Last year a major international experiment was carried out confirming the reality of superdistant contacts. And this enables us to postulate the possibility of such contacts not only on the Earth, but also in space, to assume that we are not the only ones in the universe. We think that life on the Earth is a process with cosmic participation. That is, the appearance of mankind resulted from the coinciding of definite predisposing situations on the Earth and in space. It is no easy task to prove this convincingly, but nevertheless we will attempt to do this.

And in order to concentrate efforts on research in these directions, in order to find promising solutions of terrestrial problems, including medical, we also have organized ourselves into a special group. I would even say that our institute is the prototype of a new system of organization of science in our country.

Serdtsev: Is this a private institute?

Marchenko: Certainly that can be said. Although I nevertheless have difficulty in defining its form of ownership. The founders are the Institute of General Pathology and Ecology of Man and the AMC Ltd., scientists and businessmen, citizens of Russia, Spain and France. The general director of the MIKA is Aleksandr Trofimov, candidate of medical sciences, and the president is Academician Vlail Kaznacheyev.

The work of the new institute did not start from "scratch." Over a period of many years the Institute of General Pathology and Ecology of Man, whose director continues to be Vlail Petrovich Kaznacheyev, studied field forms of life, interaction of people at a distance and the influence of space on man. The research was possible in large part due to the points of view and role of Vlail Petrovich himself. Nevertheless the institutes of the Siberian Department are open and funded for carrying out work in very definite directions. Now, in organizing a new institute, we can conduct research without evoking further unfavorable criticism from our colleagues, and we can work freely.

A special feature of our institute is that its structural units are not laboratories, but instead are scientific programs. Scientists from different institutes of the country and from abroad are coming together for conducting research within the framework of such programs. The first program carried

out by the institute was devoted to a study of the immediate sociomedical, psychological and biological consequences of the collision of the Shoemaker-Levy comet with Jupiter.

Serdtsev: Did the materials from this research serve as the basis for the first number of the VESTNIK MIKA?

Marchenko: Yes, they have been published and are open for analysis. It is impossible to tell in detail about all these studies and therefore I will only say that the participants in the research noted more than a few unusual phenomena during the period of "bombardment" of Jupiter by the comet. In particular, they state that a decrease in the magnetic susceptibility of the body of healthy persons, anomalies of the frequency-temperature parameters of quartz transducers, an increase in calls for emergency medical aid at the near-midday hours from women in the age group 20-39 years and a decrease in the viability of a cell monolayer were registered. For the time being, to be sure, we cannot confirm the presence of a direct cause-and-effect relationship. We will speak only of synchronous coincidences. But we postulate the possibility of such a relationship.

In addition to materials on the "Jovian catastrophe," in VESTNIK there also are articles under the rubric "World Enigmas, Problems: Position of the MIKA." In the first number we give our credo and an appeal to scientists and politicians.

Serdtsev: What is the reason for this appeal? Why was it issued?

Marchenko: We are alarmed by the scenario of "saving the Earth" from the threat from space developing during recent years.

The International Conference on Problems of Protection of the Earth Against Collision With Dangerous Space Objects was held in the autumn of last year at Chelyabinsk-70. We organized there the section "Problems in the Ecology of Near Space."

I was at the conference and attentively listened to all the presentations, especially the address by Edward Teller, the "father of the hydrogen bomb." The 86-year-old American scientist energetically won approval of the idea of conducting a nuclear experiment in space. He proposes using a nuclear charge in an attempt to annihilate a dangerous space object.

The conference was excited by the collision between the Shoemaker-Levy comet and Jupiter. An analogy was drawn with the Earth. In actuality, if our planet is hit by such an object life on the Earth will cease to exist. But who can say with assurance that by clumsy nuclear experiments in space we will not harm ourselves more than a comet would? Who can predict the processes which will begin on the Earth after an explosion in space?

Near space is an important structure in the interaction between space and the planet Earth. It is not precluded that it exerted an influence on the evolutionary essence of man, on his appearance and his intellect, and therefore such an experiment also may inflict a blow on mankind. Does man have a right to exercise such a freedom of his will?

This question is perhaps the key question in a program article by Academician Kaznacheyev entitled "Institute of Man or Mankind?"—also published in the first number of VESTNIK MIKA. Read it because it contains many interesting ideas...

I followed the advice of Marchenko. I will not try to retell the content of the academician's article. I will cite only several excerpts from it:

"It is entirely evident that after an ecologic crisis on Earth we also will expect an ecologic crisis in near space. These are very alarming materials which for the time being are still not coming to the attention of special commissions of the UN and the public. Mankind still has not recognized the appearance of a new real threat in connection with the possible use of nuclear missile impacts and other technical equipment in near and distant space. Man has still not been recognized that he is dependent on space the same as on any living formation in the biosphere. Here we ought not forget the words of K. E. Tsiolkovskiy that we are children of space and it is beyond our power to master the planet and space in the interests of strictly human pretensions or to seek enemies in surrounding space, thinking that we are the only reasonable form of life in space.

According to the concept of living space which we have proposed the entire evolution of the universe, beginning with the big bang, had its beginning from living space. All the biocosmic and inert matter, the matter of the stars and planets, is a manifestation of the living space principle. In actuality, there is a limited number of such planets as the Earth, but this does not mean that the sun itself and the stars and the space which surrounds these formations are without life. All this space is the totality of gigantic cosmic living flows and a living organization of which we are only a part, the elements of this living space. The setting up of an international institute not of man, but of mankind, in which the whole of humanity is regarded only as an element, a derivative of living space and the evolution of our universe, is one of the most important and possibly the sole way to bring us together for solving problems related to the preservation and survival of the planet and opposition to technocratic, purely tactical actions.

If any of the Novosibirsk scientists can share their observations about immediate and remote aftereffects of the collision of the Shoemaker-Levy comet with Jupiter and if they are interested in the possibility of cooperation with the International Institute of Space Anthropoecology they can telephone: 39-14-33, 39-98-66.

Russian Space Activity Continues Despite Problems

957A0121B St. Petersburg SMENA in Russian 26 Jan 95 p 3

[Article by Aleksey Oreshkin: "There Are No Cosmodromes in Russia. Rockets Are Launched Without Them"; the first paragraph is an introduction]

[FBIS Translated Text] Today Russia does not have a single cosmodrome of its own. Plesetsk for the time being is not ready to perform all the functions assigned it and the announcement of Plesetsk as the first Russian cosmodrome by a presidential decree was a purely political decision. In order that this "main launch center" begin to

perform the functions of a cosmodrome on a full scale it is necessary to construct: an oxygen-nitrogen plant for the production of rocket fuel, a test site complex and most importantly, a launch complex for the launch of heavy boosters (the presence of the latter distinguishes a cosmodrome from a launch center).

Nevertheless the "political solution" in this case does not mean that this decision serves only the function of a slogan. In the opinion of Sergey Gorbunov, chief of the press center of the Military Space Forces of the Russian Federation, the awarding of the cosmodrome status to Plesetsk is necessary for the initiation of construction. Two to three trillion rubles are needed for carrying out the necessary construction.

Incidentally, the Military Space Forces of Russia also require 3 trillion in order to function normally in 1995. For the time being the draft budget provides 400 billion rubles for this, whereas a total of 3 trillion has been allocated for the entire Ministry of Defense.

In the future Svobodnyy in the Far East should become a cosmodrome—the principal center for tests of military-space equipment. Gradually the entire military program will be transferred there from Baykonur because the now existing launch of reconnaissance satellites from the territory of another country is international nonsense. Bringing Svobodnyy up to the condition of a cosmodrome will require 4 trillion rubles and 7-8 years of construction. However, it is planned that launches of "Zenit" rockets of the medium class will begin there as early as 1997 (now they are launched only from Baykonur). A high percentage of the reconnaissance satellites, including those photographing the Earth's surface for peaceful and military purposes, also will be launched from there, from Svobodnyy. Each such space "camera" weighs about 5-6 tons and is loaded with photographic film 50- 60 cm wide for making a panoramic survey.

With respect to the purposes of the launches: during the recent past 30% of the satellites were civilian and accordingly 70% were military. The conversion process naturally has also affected the space arena. Now the ratio of military and space satellites is approximately 50-50. It is felt that the priority direction is the launch of so-called "dual purpose" satellites. (According to existing international agreements it is forbidden to launch into space only nuclear weapons and military vehicles, that is, space vehicles with which it is possible to launch assault missiles.)

The restructuring of personnel also is proceeding in the same direction: dual-purpose units are being organized. This is a sort of compromise, the need for which arose after the separation of the Military Space Forces (MSF) into two parts: military, with the very same name—Military Space Forces—and civilian—Russian Space Agency. The leadership was retained by the military. This can be seen very clearly in the example of the Baykonur cosmodrome, leased from Kazakhstan for 20 years for 115 million dollars a year (some of this sum will be written off due to debts owed by Kazakhstan to Russia).

Russian families from Baykonur are now being resettled due to the shortage of funding. It has been decided to reduce personnel by almost half—from 25 000 to 12 000. The reduction is transpiring for the most part at the expense of civilian service personnel, which somewhat contradicts another decision, according to which the funding of the workers of the Military Space Forces should be from the civilian Russian Space Agency. But for the time being it does not have a great number of orders, although satellites could find broader use in all branches: in agriculture and navigation. However, at present this is not too popular and evidently not too cheap. Precisely where are they used, is it in military operations, in which we are now engaged in great number? The representatives of the press center do not have data on the use of military space vehicles in the Chechen conflict. The commander of the Military Space Forces, recently visiting St. Petersburg, declines to answer such questions, but in the opinion of engineers of the Military Space Forces and a representative of the press center of this department the probability that space vehicles are being used is about 99% (if for no other reason than because a preliminary survey from space increases the efficiency of bombings by at least twice).

The extrication from a situation in which the civilian part of the space forces (now the RNA) must fund the military part—the MSF—is very simple; formerly being a unified department, it again is being brought together, but at a low level: mixed-purpose units are now being organized.

Similar processes are transpiring with military technology: boosters and space vehicles which once were purely military are becoming technology for this same type of mixed operation. For example, the boosters used in the "RS-18" combat system must be destroyed in accordance with the well-publicized Start II arms control agreement, but to "burn up" such hardware would be downright madness and therefore it has been reoutfitted, being transformed into "Rokot" boosters. The launch of the first such booster took place from the Baykonur cosmodrome early on the morning of 26 December. It put into orbit the "Radio Rosto" amateur satellite, built in commemoration of the 100th anniversary of invention of the radio by Aleksandr Popov. To be sure, however, it was not at all for assistance to radio amateurs that such an expensive vehicle was launched; this was but a secondary purpose.

The principal purpose was the testing of the new booster. Prior to this "Rokot" launches had been made only on ballistic trajectories (that is, on trajectories ending on Earth, not in orbit). After a series of experimental launches the "Rokot" boosters will put low-flying communication satellites into orbit (evidently, all for this same mixed purpose).

Each month 1-3 satellites are launched (50 were launched during the past year). On 24 January a "Kosmos" booster was launched from the Plesetsk cosmodrome. It put into orbit 2 satellites each weighing 100 kg: Swedish Astrid and American Fisat satellites and our own space vehicle for sea navigation. The "Foton" space vehicle should be put into orbit in mid- February. The cosmonauts affectionately call it the "Sharik" (not in honor of the dog, but simply due to its similar configuration). The "Sharik" will be used in carrying out biological experiments, in particular, for carrying out purification of biopreparations (such as insulin) under weightlessness conditions. Thus, despite the temporary absence of cosmodromes, to speak of the death of Russian cosmonautics would be possible only by being a hardened pessimist.

Organizing Test Range for Certifying Satellite Receiving-Computation Complexes

957A0066A Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 2, Feb 94 pp 10-13

[Article by A. A. Genike, V. S. Kislov and L. S. Yunoshev; UDC [528.5:629.783].089.6]

[FBIS Abstract] Satellite GPS technology is progressing rapidly. Any improvements must be subjected to the strictest metrologic and certification tests, but until recently there have been no fully adequate schemes in Russia for accomplishing this. A metrologic test range was therefore established on the grounds of the Institute of Time and Space Metrology for precise evaluation of geodetic satellite receiving-computation complexes, as were two other ranges extending over greater areas. By the beginning of the 1993 field season some of these ranges were ready for use in research and testing of such apparatus. The full test range complex is divided into three parts, each satisfying particular testing needs, each of increasing complexity; each geodetic construction is illustrated and described in detail. The first, of the most limited extent, is to meet the needs of users developing small local geodetic networks based on GPS technology; the second, more complex, is intended for metrologic certification of satellite apparatus and for developing optimum technologies to be used in building or reconstructing reference geodetic networks of different orders; the third, the most complex, is a geodetic construction with sides tens and hundreds of kilometers in length for in-depth satellite technology research to be applied when constructing networks extending over much greater areas. In each case the problems involved, the instruments and procedures employed and the accuracies achieved are discussed. This group of test ranges even now makes it possible to carry out certification and metrologic verification work related to use of GPS satellites. This will make possible an objective evaluation of the accuracy of satellite measurements fully meeting the needs of users. Figures 3; references: 1 Russian.

Geodetic Control of Surface Space Complex Launch Structures

957A0066B Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 2, Feb 94 pp 18-22

[Article by V. A. Kalashnikov and V. I. Starodubtsev; UDC 528.489:656.71]

[FBIS Abstract] The system for geodetic control (GC) of the spatial stability of foundations and structures at spacecraft launch pads is discussed. An annotated figure schematically represents the launch complex for ships of the Buran type at Baykonur. By "spatial stability" is meant absence of inadmissible movements and deformations of individual structures, equipment and the launch complex as a whole. The evolution of this system during the years which have elapsed since the first launches is discussed, followed by some specific examples of the development and use of the GC system and a generalization of experience with its use. The specific climatic conditions at Baykonur restrict geodetic measurements to the months April through October. In summer measurements can be made for only 2 hours after sunrise and 1.5 hours before sunset; at other hours the excessive temperatures cause inadmissible refraction and thermal expansion of structural elements and geodetic instruments. These conditions impose strict limitations on the distance from which measurements can be made. The type and placement of measurement base and structure bench marks and triangulation and trilateration procedures are discussed in some detail. Some of the observed movements and changes in other parameters are described relative to the stipulated tolerances. The unique problems which sometimes arise are mentioned. The brevity of the article precludes presentation of all details and such matters as determination of the parameters of absolute movements of structures at the time of actual launches are not discussed. Figure 1; references: 3 Russian.

Interactive Interpretation Method

957A0066C Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 2, Feb 94 pp 38-41

[Article by V. S. Biryukov and G. N. Gamayunova; UDC 528.77:65.011.56]

[FBIS Abstract] An interactive interpretation method is described, based on formalization theory, for a variant of image identification making use of indicators determined visually by the interpreter from one black-and-white image in the form of a photograph or a digital representation of a photograph on a display screen. This involves use of an SM 1420 computer, graphic and half-tone displays and a printer. The method requires use of a set of programs developed at the Priroda State Center for interpretation of the images of a number of linear features pertinent in map revision work. Since use of the method involves additional time expenditures in interpreter-computer dialogue, its use is therefore desirable when it is necessary to increase interpretation reliability, such as when feature identification is in doubt. An increase in work productivity and interpretation reliability is possible by automatic determination of some of the indicators present in the digital images. An identification program which was developed provides for the possibility of input of indicators whose quantitative values are determined automatically. The proposed interactive interpretation method is universal because when organizing appropriate image and indicator banks it is fundamentally suitable for the processing of point, linear, areal, black-and-white and color radar and other images. Specialists at the Priroda State Center can fill orders for setting up and delivery of image and indicator banks and can deliver and put into operation the necessary technology for interactive interpretation work and performance of work on automated image interpretation.

Fundamental Conversion Problems in Topography

957A0066D Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 2, Feb 94 pp 41-43

[Article by S. V. Agapov; UDC 623.64]

[FBIS Abstract] Conversion in the field of geodesy, cartography and topography is highly important for the economy and unlike conversion in other military fields this can be accomplished without great expenditures. The conversion discussed here refers to the effective use in the economy of

the theoretical, technical and technological resources accumulated by the military topographic department over the many years when all military development work was carried out under a cloak of secrecy. Everyone must be given access to these materials. There must be open publication of many materials which should never have been classified in the first place. Examples are mathematical models of aerospace photographs obtained by nontraditional survey systems, many kinds of technical equipment and technologies for photogrammetric processing and means for automating the stereoscopic processing of photographs and editing of topographic information in the final stages of compilation or revision of topographic maps. There must be a cooperation between military and civilian specialists such as has never existed in the past. Although certain materials may justifiably be kept secret, every effort must be made to ensure that this is warranted. There is a dichotomy between military and civilian topographers in that the former employ primarily Russian technology, whereas the latter strongly emphasize use of foreign instruments. Steps must be taken to ensure that all these assets be exploited to the maximum in meeting practical economic needs. There must be an interexchange of military and civilian resources and experience since most civilian topographers during wartime perform many military tasks. During peacetime military topographers must not only convey their know-how to civilian topographers, since they constitute a backup for the military, but the military also must make use of everything which is new and progressive in nonmilitary organizations.

New Technologies in Computer-Aided Cartography

957A0066E Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 2, Feb 94 pp 47-50

[Article by A. I. Martynenko; UDC 528.92:65.011.56]

[FBIS Abstract] This is a review of work done by Russian and foreign cartographers during recent years in the field of computer-aided cartography, with one of the stressed priorities being the field of organizing and upgrading of geoinformation systems (GIS). Among the other priority directions discussed is the development and production of electronic maps. Another important undertaking is in the field of construction of three-dimensional terrain models obtained by analytic and digital methods, as well as a television survey of such models. Still another progressive area is the development of methods for automatic image recognition and cartographic generalization (computer-aided generalization is a key consideration in GIS). Due to computer technology advances in the next 10-15 years there will be corresponding rapid changes in cartographic technologies, favoring development of a new generation of interactive work stations. However, the further development of new technologies in Russia is dependent on introduction of a national standard for digital and electronic maps. The standards used abroad and those proposed for Russia are discussed. The following directions are pertinent for the new technologies: a systemic approach as a conceptual basis for organizing and using GIS and also as a method for investigating and planning a system of cartographic models (digital and electronic maps) and developing effective computer technologies; mathematical-cartographic modeling of processes for the identification and generalization of the cartographic image as a method for depicting terrain elements and features; screen input/output of cartographic information, its processing and storage in vectorial form; controllability of spatial data; the most complete possible collection of spatial data, their exhaustive analytic-synthetic processing and repeated use; development of artificial intellect and knowledge base systems on the basis of modeling algorithms and programs.

Determining Points of Reciprocal Overlapping or Intersection of Terrain Features Represented in Digital Form

957A0066F Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 2, Feb 94 pp 50-51

[Article by V. I. Kaminskiy, V. G. Pleshkov and I. V. Sidorov; UDC 528.92:65.011.56]

[FBIS Abstract] One of the most important problems in digital mapping is automation of the processes involved in compiling topographic and thematic maps and preparing them for publication on the basis of a digital representation of cartographic information. Successful solution of the problem requires not only information describing terrain features, but also allowance for the interrelations between them. The topologic interrelations are examined here. With a reduction in map scale and the plotting of new data inadmissible overlappings and intersections of features often arise in the geometric presentation. The detection of overlapping or intersecting features is important when generalizing relief forms by use of structural lines. The proposed method provides for two stages in determining the points of intersection or overlapping of linear (areal) features. In the first stage the digital information on the map sheet is distributed by squares forming a regular grid seemingly superposed on the map image. The second stage is discrimination of informative elements which contain two or more features. The number of features present in it, the code and number, as well as the address of the beginning and end of the segment belonging to the feature passing through it, are taken into account in each case. The method was experimentally checked using a model containing 180 linear features. The intersections were detected automatically using a personal computer. Using the developed program the digital information was distributed by matrix elements. After excluding from further processing the matrix elements containing less than two features the remaining elements were grouped and later combined into a file. As a result all the intersections were registered, the coordinates were computed for them and the codes of the intersecting features were determined. References 5: 3 Russian, 2 Western.

Highly Precise Coherent Phase-Type Laser Range Finder

957A0064A Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 7, Jul 94 pp 18-22

[Article by A. A. Abramyan and G. R. Yedigaryan; UDC 528.51]

[FBIS Abstract] The described phase-type laser range finder is based on the three-channel frequency principle.

Each of these channels is intended for precise and unambiguous range measurements. All three frequency oscillations are formed in the transmitter by means of a highly stable microwave oscillator, low-frequency oscillators and phase-compensating units. The laser beam is modulated by an electrooptical modulator. After covering the distance to the reflector the modulated laser beam is fed to the input of an electrooptical demodulator. Since the channel frequencies are close to one another, beat detectors are cut into the range finder circuit in order to increase the range of unambiguous range measurement. A block diagram, with 23 components identified, is used in clarifying the structure and functioning of the instrument. The principal merits of this range finder include: a virtually instantaneous visual numerical readout of range without readjustment, computations or corrections; a high instrumental measurement accuracy; possibility of unambiguous measurement of great ranges. The high coherence of oscillations in all transmitting and receiving circuits makes possible automatic frequency and phase self-compensation of all the initial phases of oscillator oscillations and undesirable phase irregularities in their circuits. The principle of simultaneous modulation and demodulation of the laser ray by three oscillations of the scale frequencies makes it possible by phase compensation units and LF oscillators to reduce the number of high-frequency, highly stable scale-frequency oscillators to one and to form the necessary number of frequency channels. These features make it possible to reduce the size and weight of the range finder and upgrade operational stability and reliability. Figures 2; references: 3 Russian.

Determining 'Standard' Positions of Space Vehicle

957A0065A Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 4, Apr 94 pp 10-13

[Article by B. I. Vlasov; UDC [528:629.783].089.6]

[FBIS Abstract] The accuracy of range measurements to spacecraft governs the reliability of modern geodetic constructions, but all systems for measuring range to moving objects are encumbered by systematic errors of two types: multiplicative and additive. Both are discussed, but emphasis in this article is on the additive type, governed by the fact that the time interval between commands for registry of the beginning and end of the process of propagation of an electromagnetic signal in space is not equal to the duration of this process. The problem is somewhat different for radio and laser range finders (the latter can be used in checking the results obtained when using the former); the case of optical range finders also is considered. The algebraic sum of the delays forming the additive error may exceed tens of nanoseconds, depending on instrument design. A series of distorting influences may make determination of the additive error difficult, but ways to eliminate these are proposed. A "standard" positions method is proposed as an alternative to traditional methods. It is based on purely geometric self-determination of range finder additive errors without using reference instruments and models of spacecraft motion. This method is clarified by three geometric figures accompanying the text (two approaches for problem solution are described). Formulas are derived for making corrections for the additive error. The described method for obtaining "standard" spacecraft positions also can be used when determining ranges by measuring the duration of signal propagation in a single direction if the additive error for each measurement point remains the same in each measurement interval. Such cases occur, for example, when the measurement points at which there are sufficiently stable clocks receive signals from similar clocks aboard spacecraft. Figures 3; references 4: 2 Russian, 2 Western.

Automated Information System for Local Geodetic Networks

957A0065B Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 4, Apr 94 pp 26-29

[Article by V. N. Poleshchenkov and I. A. Zelenina; UDC 528.3:681.3]

[FBIS Abstract] The Siberian Geoinformation Center has developed an automated information system for local geodetic networks (AIS LGN) which performs the functions of input, correction, storage, revision, data processing, precomputation of accuracy, planning of horizontal-vertical geodetic networks of any order of accuracy and output of data upon interrogation with its dissemination in set formats to a user or another information system, as well as other functions. Each of these functions is briefly described. A personal computer menu is provided for use in executing these functions. The wide range of specific problems which can be solved is summarized, as are the information functions. All these functions are performed in two fundamentally different modes, which are described. In the first mode, as geodetic information is accumulated, the AIS LGN automatically shifts to its processing or reprocessing. In the second mode a menu is displayed from which the user himself interactively selects the AIS LGN function which he requires. In this mode the user can obtain exhaustive information in the area of interest. The AIS LGN performs automatic checking of computations and affords a possibility for visual checking by display or printout of special documents. In the AIS LGN all data are in two forms: external and internal. The output of geodetic information stored in the system is by interrogation by a user making use of convenient menus and prompts. The many different kinds of output documents are listed.

Organizing Space Images Database

957A0065C Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 4, Apr 94 pp 33-36

[Article by A. M. Buzhurin, V. M. Vaskin, M. A. Selyukh and A. V. Smurygin; UDC 528.7(202)(084.121): 65.011.56]

[FBIS Abstract] It is proposed that databases be organized for storing qualitative and quantitative reference data concerning individual space images and series of such images. At present there is danger that geographic, economic or other studies could be undertaken without exploiting available space photo resources and there is presently no effective means for evaluating their potential usefulness. It is stressed that this does not involve storage of a digital image of each photograph. The database must

be supported by a complex of dialogue and graphic devices making possible logical processing of image parameters and graphic interpretation for possible use of these materials in solution of practical problems. Such complexes can be set up at minimum cost. The different steps involved in constructing a space images databank are outlined. The designing of a conceptual model is highly important because it governs the logical correlations between the stored information, in the initial stage making it possible to form the structure and content of the stored information and thereafter ensuring a possibility for improving, modifying and supplementing its structure. Provision must be made for a backup in the event that the database is destroyed. The database is based in an IBM PC; the database software is discussed with emphasis on data retrieval. The software serves as an expert advisor which for each specific region determines the full list of topologically intersecting runs of space images whose attributes are stored in the databank files and which with the ready access envisioned can be retrieved as desired by a wide range of specialists. Figure 1; references: 3 Russian.

One Contradiction in Projective Geometry of Great Significance for Photogrammetry

957A0065D Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 4, Apr 94 pp 36-38

[Article by S. V. Agapov; UDC 528.71:513.17]

[FBIS Abstract] A number of fundamental principles of projective geometry applicable in photogrammetry are reviewed. The "homocentric" bundle considered here, in contrast to other such bundles of rays considered in projective geometry and photogrammetry, refers to the set of straight lines (rays) and planes passing through a single point. A homocentric bundle of projective rays does not fully ensure a projective transformation of the plane in accordance with the traditional formulas. In photogrammetry problems frequently arise when the optical system (objective) forms only a homocentric bundle of projecting rays with a characteristic center. The seemingly applicable formulas reflect only a special case of affine transformation of planes, specifically a conformal transformation. Accordingly, a homocentric bundle of projecting rays cannot without reservation be set in unambiguous correspondence with the projective plane because this contradicts the property of complexity of the projective representation in the traditional analytic expression, taking in all special cases of such a transformation (without any exceptions). In a homocentric bundle there can be only an oblique transformation of the plane, precluding its affine transformation in general form, since two affinely corresponding planes cannot be positioned in it in such a way that their corresponding points fall in one bundle ray and the corresponding straight lines fall in the same plane. The geometric representation of the projective transformation of a plane in a homocentric bundle therefore contradicts its analytic representation as defined by the traditional formulas. References: 5 Russian.

Mapping of Indices of Level of Social Development in Different World Countries

957A0065E Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 4, Apr 94 pp 43-48

[Article by I. A. Rodionova; UDC 528]

[FBIS Abstract] A series of maps of various indices makes possible a detailed and graphic characterization of the socioeconomic structure of society. This is illustrated by two maps which accompany the text: daily dietary intake of calories as percentage of physiological requirements and expenditures on food as percentage of income, both of which make clear the country-by-country prevalence of undernutrition, hunger and starvation. The information conveyed by these two maps is discussed. These mapped indices make it possible to compare the situation throughout the world with conditions prevailing in Russia and the CIS countries, although it is stressed that the mapped national indices fail to convey the fact that within the borders of the former USSR (and in most other countries) there is one percentage or another of the population, the economically advantaged, which is well-fed, with a fully adequate nutritional level. Within the former USSR this socioeconomic-nutritional gap is rapidly increasing. The same picture is observed for the countries in Eastern Europe (in Hungary 20% are at the poverty level, in Romania—50%). Most of the material used in compiling the maps was drawn from WHO-FAO reports, which also indicate that world food resources are adequate, but its distribution is totally inadequate. The published maps therefore do not tell the entire story, but other maps in the proposed series would rectify this shortcoming. Since economic situations change and new statistical data become available, these and similar maps naturally require routine revision. Figures 2; references 6: 5 Russian, 1 Western.

Conceptual Principles for Plotting and Using Electronic Maps

957A0065F Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 4, Apr 94 pp 54-56

[Article by Ye. I. Khalugin and A. I. Maydanich; UDC 528.65.011.56]

[FBIS Abstract] Modern automated mapping systems are unsuitable for compiling electronic maps with respect to such important indices as universality, interactivity, generalization, storage and editing procedures due to the formally syntactical model on which these systems are based. It is therefore essential to find such methods and models which would make it possible to convey the semantics and pragmatics of cartographic generalization. All this dictates use of means for storage, editing and systematization of rules governing generalization. In applying methods for the selection and generalization of features on electronic maps provision must be made for means for taking into account qualitative characteristics having a broad range of values and properties as well as means for the control of generalization not requiring from users mastery of programming languages or other special skills. Such problems can be solved only by using approaches employed in unformalized fields. The advances made in

the theory of an artificial intellect, particularly in the development of expert systems, make it possible to use these systems as the most effective tool for the automatic compilation of electronic maps. The methods of the theory of situational control were used in constructing a logical-linguistic generalization model meeting all the formulated requirements. A model language, constituting a problem-restricted natural language, has made possible an adequately expressive description of generalization regularities and the prevailing situation. These and other steps have made it possible to determine the internal structure of components of the expert system for automated selection of features. Experimental checking of these and other conceptual principles is described in the example of compilation of specific maps.

Regionalization of Terrain Using Results of Prediction of Aftereffects of Exceptional Situations

957A0063A Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 9, Sep 94 pp 38-43

[Article by V. I. Ivanov, V. V. Mitrofanov and S. V. Trubach; UDC 528.946:303.444]

[FBIS Abstract] In developing a system for obtaining the results of prediction of the aftereffects of exceptional situations of a technogenic, natural or ecologic nature the need arises for their graphic representation in the form of zones constituting uniform surface sectors. Until now the regionalization of an area, with defining and representation of such zones, has been accomplished using topographic and thematic maps at 1:10 000-1:1 000 000 or materials from remote sounding of the natural landscape. But these methods do not take into account the unequal influence of the various factors and properties governing the conditions for zoning a particular area and all factors are not always taken into account. There is only a qualitative evaluation, much work is involved and subjectivity is a serious problem. An automated quantitative regionalization method is therefore proposed as an alternative. It is based on the results of prediction of the aftereffects of possible accidents, calamities and epidemics. The most promising variant is representation of the regionalization results directly on topographic maps. The method, described in detail, makes possible a routine quantitative prediction of different factors and thereby gives both an integral evaluation of surface sectors with respect to the impacts exerted on them by such aftereffects and particular evaluations characterizing the ecologic conditions in the studied area as a function of the influence of individual properties (factors). The regionalization process is automated by use of mathematical models of the terrain, climatic, geologic and other conditions and analytic methods for predicting these aftereffects. The final prediction results, expressed in quantitative terms through dimensionless indices, with the components properly weighted, ensure obtaining necessary data for arriving at a correct and objective solution and appropriate measures for creating suitable ecologic conditions, lessening the risk of loss of human lives and destruction of industrial facilities. Figure 1; references: 5 Russian.

Relief Influence on Pollution of Urban Area (Exemplified by Izhevsk)

[Article by V.I. Sturman, Udmurt State University, UDC 551.588.7(470.51)]

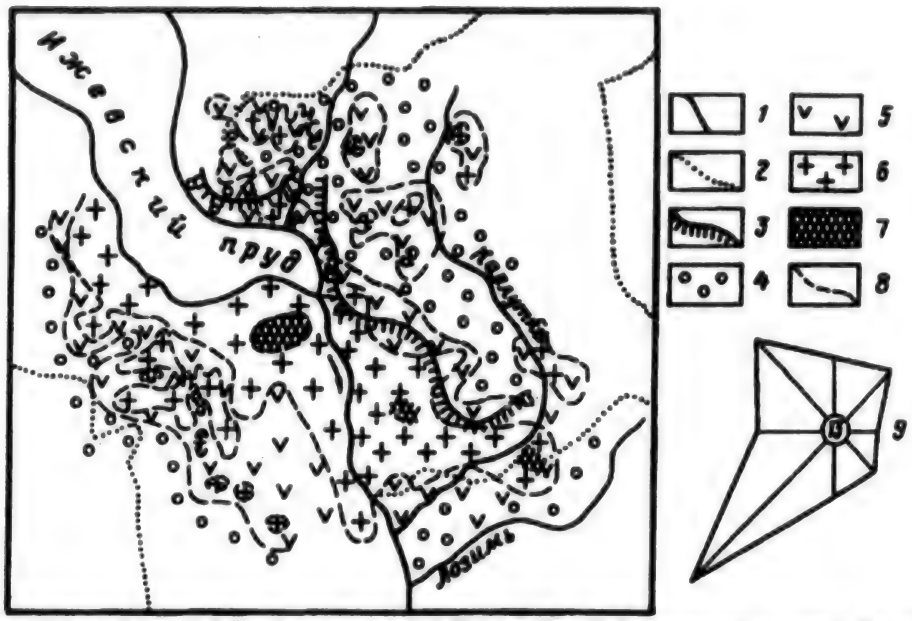
957A0062A Moscow GEOMORFOLOGIYA in Russian No 4, Oct-Dec 94 (manuscript received 28 Jan 93) pp 29-31

[FBIS Translated Text] The current method for computing the atmospheric dispersal of harmful effluent [1] provides for allowance for the influence of relief only when there is local relief greater than 50 m/km, since with lesser differences the corresponding coefficient in the computation formula is considered equal to unity. The possibilities of direct study of the state of the air medium are limited due to the thin network of posts for observing atmospheric pollution. Their number, even in the largest cities, is inadequate for detecting the complex, mosaiced pattern of distribution of pollutants.

The mapping of the media receiving this pollution—soils, snow, plant tissues and bottom deposits—affords virtually unlimited possibilities for increasing the detail of pollution studies [2]. The composition of the pollutants in dynamic media and the media in which they are deposited is different. But since the pollution sources are the same, there are correlations between the concentrations of the very same metals in the soil, air and snow [3], air and plant tissues [4] and even, according to our data, between the total indices of pollution of soils and snow and the indices of atmospheric pollution ($R = 0.723$ for 25 points in 3 cities) or only between the total indices of soil pollution and atmospheric pollution ($r = 0.515$ for 53 points in 9 cities) [5]. The degree of pollution of soils and snow by metals reflects the presence in the air not only of these metals, but also the other most commonly observed ingredients, such as sulfur dioxide, nitrogen dioxide, carbon monoxide and dust [2, 5].

We studied the pollution of soils and snow by metals in Izhevsk by the method developed at the Mineralogy, Geochemistry and Crystal Chemistry of Rare Elements Institute (IMGRE), Russian Academy of Sciences [6]. Definite patterns in the distribution of aerogenic geochemical anomalies are traced on the multi- and monoelement maps which were plotted.

The most significant anomaly, with respect to both intensity and area, is located in the depressed central part of the city where the largest machine-building metallurgical complex is situated. The eastern edge of this anomaly coincides with the left bedrock slope of the Izh River valley with a steepness 3-5° and a relative height 50-60 m. This edge of the anomaly is relatively distinct: a transition from a dangerous pollution level (total index Z_{tot} from 32 to 128) to an admissible level (Z_{tot} up to 16) occurs in a band with a width from 100 m to 1 km. The western edge of the anomaly, corresponding to the gentle right slope of the Izh River valley, is blurred and has a greater width. The northern edge of the anomaly runs across the surface of the pond; the southern edge merges with hydrogenous anomalies in the Izh River floodplain. The figure shows that in the horizontal plane the configuration of the anomaly is virtually unrelated to the wind rose. The anomaly is drawn out in a southeasterly direction despite a prevalence of southwesterly winds,



Sketch map of pollution of area of Izhevsk adjacent to Izh River valley. 1) hydrographic network; 2) outline of built-up area; 3) brow of left bedrock slope of Izh River valley. Levels of soil pollution by metals: 4) admissible (Z_{tot} up to 16); 5) moderately dangerous (Z_{tot} 16-32), 6) dangerous (Z_{tot} 32-128), 7) excessively dangerous (Z_{tot} 128), 8) boundaries of sectors with different pollution levels, 9) wind rose for Izhevsk (year) [7]. Upper left: Izhevskiy Pond; lower right: Pozim River; right: Karlutka River.

which is attributable to a combination of factors, including a deflection of the air flow in the surface layer in the direction of the broad floodplain at the confluence of the Izh, Pozim and Karlutka Rivers. The considerable coincidence of the boundary of the anomaly area and the slope brow (see figure) gives basis for concluding that this slope has a barrier role. The Karlutka River flows in an asymmetric valley at a distance 4-5 km to the east of the Izh River. Its relatively steep left slope (western exposure) also is a barrier limiting the spreading of anomalies associated with individual enterprises and highways.

In addition to 16 large anomalies associated with specific sources within the city and suburban zone there are more than 50 small, local anomalies whose origin cannot always be unambiguously interpreted. They are situated in the most differently laid-out urban zones: in areas of private and multistory residential structures, near small enterprises and garages, and even in suburban woods and in orchard-garden sectors. Eighteen of the 52 anomalies are associated with small positive landforms (interfluve hills known as "pugs," rises between ravines), which multiply exceeds the fraction of the mentioned landforms in the territorial structure. However, if one subtracts from the 52 small anomalies the 13 associated with specific pollution sources, their fraction becomes still more substantial. Among the 18 small anomalies associated with positive landforms, 16 are situated near the western, southern and eastern edges of the principal anomaly (see figure) and as a rule are close to it in composition. It is probable that gas-dust effluent of industrial enterprises precipitates more intensively on uplifted landforms. In small negative forms (gullies, ravines) pollution is reduced in comparison with ambient sectors.

Thus, the relief of Izhevsk exerted an unambiguous influence on the redistribution of pollutants. Relatively large forms (river valleys) exerted an active influence on the redistribution process, changing the local circulation. The role of small landforms in the redistribution of pollutants can be regarded as passive. Here the distance from the ground surface to the air layer situated at some height at which a maximum of pollutant transport occurs, determined by microrelief, probably exerted an influence. Judging from the local relief of small landforms, the height of this layer (or at least its lower boundary) does not exceed a few tens of meters.

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Environmental Pollution and Radiation Conditions in the Territory of Russia in August 1994 (Official Information of the Russian Hydrometeorological Service)

957A0076 Moscow METEOROLOGIYA I GIDROLOGIYA in Russian No 11, Nov 94 (manuscript received 27 Sep 94) pp 122-124

[Article by A. M. Ovanesyants, N. A. Belova, V. A. Savelyev, Federal Service of Russia on Hydrometeorology and Environmental Monitoring; UDC 504.3.054]

[FBIS Translated Text]

Environmental pollution due to accidents

Air. No reports of accidents with atmospheric emissions of pollutants were submitted in August.

Water. There were three accidents reported which affected bodies of water.

On 13 September information was obtained from the Committee on Environmental Protection of the Republic of Komi about an accident which occurred in August 1994 along a pipeline between Vezi and the main facilities of the oil and gas extraction administration, Usinskneft.

Several cracks developed in a part of the pipeline located in poorly accessible marshes, and an oil spill occurred.

The Komineft joint stock company, which owns this pipeline, knew about the accident on 17 August 1994, but did not report it to local environmental protection agencies, the MChS [expansion not given] of Russia and the Russian Hydrometeorological Service. Investigation of the circumstances of the accident is continuing.

On 27 August an accident at the Nizhniy Tagil electric power plant caused pumps to shut down which delivered waste water into the west treatment system. As a result, more than 60,000 m^3 of untreated waste water entered the Tagil River. The situation was corrected on 28 August.

On 29 August in Tula a sewage collector 1400 mm in diameter broke and three pumping stations shut down. The waste water flooded several hundred square meters of a residential area and polluted the Upa River. Repair work is continuing.

Soil. On 28 August near Mavrinka in Saratov oblast the Samara-Lisichansk oil pipeline cracked. The total volume of oil that was spilled was about 6000 m^3, which polluted more than 30 hectares of farm land in the Pugachevsk and Ivanteyev regions of the oblast. No pollution of bodies of water was detected.

Extreme levels of environmental pollution

Air. There were no reports of extreme pollution of air in August 1994 (or August 1993). Extreme pollution is defined as exceeding the maximum one-time maximum allowable concentrations in a 20 minute period of observations 50 or more times or exceeding the average daily maximum allowable concentrations 30-49 times.

Water. On 9 August, during planned repair of the city treatment equipment for Vologda, untreated waste water from residences and businesses entered the Vologda River. As a result the concentration of dissolved oxygen in the river decreased to an extreme level, 1.2-1.4 mg/l, and the content of nitrite nitrogen and organic substances increased to 12-15 times the maximum allowable concentration (MAC) according to the biocheical oxygen demand, BOD_5.

As before, extreme pollution was reported for rivers: Pelshme in Arkhangelsk oblast (presence of hydrogen sulfide, absence of oxygen); Neyve in Sverdlovsk oblast (shortage of disso lved oxygen in water); and Neman in Pregolya in Kaliningrad oblast (presence of hydrogen sulfide). The polluters are the cellulose-paper industry and residential construction enterprises.

High levels of environmental pollution

Air. Cases of high levels of atmospheric pollution (exceeding the one-time maximum allowable concentration 10 or more times) with class two hazardous substances were reported nine times in three cities: hydrogen chloride, up to 15 times the MAC in Omsk (two cases) and 17 times the MAC in Solikamsk; chloroform, up to 15 times the MAC (six cases) in Beloretsk (in August 1993, 18 times in four cities). In Omsk there were also two cases of high levels of pollution of acetyldehyde (up to 21 times the MAC) and two cases of ethylbenzol (up to 12 times the MAC) and in Chita, one case of a high level of dust pollution (10.2 times the MAC). In all in August there were 14 cases in four cities of pollutants in concentrations of 10 times the MAC and above (in August 1993, 32 cases in seven cities). The most frequent cases of high levels of atmospheric pollution (three times a month and more) were reported in Beloretsk, where the maximum one-time concentration of chloroform reached 10-15 times the MAC in six cases (in August 1993, in three cities).

Water. In August 1994, 166 cases of high levels of pollution of 97 bodies of water were reported.

As before, the most pollution was found in the basins of large rivers:

- the Volga and its tributaries, the Oka and Kama (more than 29% of all cases of high levels of pollution) in the territory of Moscow, Tula, Ryazan, Vladimir oblasts were polluted by ammonia nitrogen and nitrite nitrogen (10-30 times the MAC) and manganese ions (10-42 times the MAC); in Samara oblast, by chlorogranic pesticides (up to 30 times the MAC); in Sverdlovsk and Perm oblasts by copper ions (30-60 times the MAC) and hexavalent chromium (10-16 times the MAC);
- the Oba and its tributaries, the Irtysh and Tobol (more than 19% of all cases of high levels of pollution) in the territory of Novosibirsk and Tomsk oblast and Altai krai were polluted by ammonia nitrogen and nitrite nitrogen (10-30 times the MAC); in Sverdlovsk and Kurgan oblasts by copper ions (30-80 times the MAC); and in Tyumen oblast by petroleum products (up to 54 times the MAC).

Hydrogen sulfide (up to 0.004 mg/l) was found in the rivers of the Angara basin in Irkutsk oblast.

The rivers of Khabarovsk krai are polluted with copper and zinc ions (30-86 times the MAC); Sakhalin island, with iron ions (3-11 times the MAC); and Murmansk oblast, with nickel and copper ions (10-90 times the MAC).

The city of Moscow. In August, the average monthly concentration of formaldehyde in the city's atmosphere was 5 times the MAC, benzol 3 times the MAC, ammonia 2.3 times the MAC, nitrogen dioxide 2.0 times the MAC, phenol times the 1.7 MAC, and carbon monoxide 1.3 times the MAC.

The maximum one-time concentrations on individual days of the month reached the following values: carbon monoxide 6.4 times the MAC (Dolgoprudnaya ulitsa), nitrogen dioxide 4.9 times the MAC (Shipilovksaya ulitsa), ammonia 4.8 times the MAC (Bratyeyvskaya ulitsa), phenol 4.2 times the MAC (Sucharevskaya ploshchad).

Lake Baikal. As before, waste water from the Baikal cellulose-paper mill is being pumped into Lake Baikal, violating established standards for the content of pollutants: chlorides appeared in 54% of samples analyzed in August, suspended substances in 35% of the samples, and phenols and discoloration in 10-13% of the samples.

Ladoga Lake. In August of this year the "Monitoring Arctic" regional center of the Russian Hydrometeorological Service completed work on the analysis of samples taken in the course of the summer survey of Ladoga Lake at 34 stations, determining the content of heavy metals, chlororganic compounds, including polychlorbiphenyls, petroleum hydrocarbons, polyaromatic hydrocarbons, detergents, biogenic compounds, main ions, and sanitary and bacteriological indicators. Samples were taken from the lake and bottom sediments.

The results of the survey showed that of the heavy metals, ions of copper and zinc had concentrations above the MAC (up to 4-12 times) at the northwest shore of the lake, as well as at the mouths of the rivers Svir, Volkhov, Syas, and the source of the Neva.

Of the chlororganic compounds, elevated concentrations of polychlorbiphenyls (up to 4 times the MAC) were found at the northwest shore of the lake; one of the other regions with an elevated content was the source of the Neva.

The maximum values for petroleum hydrocarbons, up to 6 times the MAC were found at the north and northwest parts of the lake.

The content of detergents and polyaromatic hydrocarbons did not exceed the MAC over the entire lake.

The existence of zones of stable high levels of phenol pollution (from 10 to 40 times the MAC) in the regions of Sorta vala, Priozersk, the mouths of the rivers Svir, Volkhov, Syas, and the source of the Neva is noteworthy. This pollution is related to the emissions of enterprises in the cellulose-paper and lumber processing industries, waste from settlements, and drainage of pollutants by rivers.

Microbiological analysis of the water from Ladoga Lake revealed several shore zones with elevated (more than 5000) E. coli index (the sanitary standard is up to 1000), including the regions of Priozersk, Srotavala, and the mouths of the rivers Volkhov, Syas, and Svir. The microorganism content indicates the presence of constant fecal pollution in these regions, which is a consequence of the emission of untreated waste water from settlements and from livestock co mplexes.

All of this has caused a reduction of the self-cleaning capacity of the shore waters of Ladoga Lake in these regions, as indicated by the increased content of poorly-oxidized organic contents, according to the chemical oxygen minimum, from 40 to 135 mg O_2/l, which is several times higher than the value in cleaner, central regions of the lake.

Thus, Ladoga Lake has three zones: 1) the north and northwest shore; 2) the south and southeast shore, and 3) the central part and eastern shore. The first two zones are experiencing a constant anthropogenic load and are characterized by elevated levels of pollution of the water and bottom sediments. It is alarming that this region includes the source of the Neva, which is the source of water for St. Petersburg.

The levels of pollution in the third zone do not exceed established standards for virt ually all monitored substances.

A comparison of the results obtained in 1994 with the available data from surveys conducted in a similar manner in previous years shows that there is no trend toward worsening water quality in the lake and bottom sed iments, and one can say with some caution that the level of pollution of Ladoga Lake has stabilized.

Radiation

The radiation situation in August 1994 in the territory of the Russian Federation was stable. The concentrations of radioactive substances in the air, the density of fallout and the dosage of gamma radiation in areas outside of the

zones polluted by the C hernobyl catastrophy and other radiation accidents are within the range of fluctuations in the natural background.

The most polluted regions, the Zlynkovsk and Krasnogorsk regions of Bryansk oblast, have settlements with a local cesium-137 pollution density of more than 40 Ci/km^2. The levels of local exposure to gamma radiation are from 50 μR/hr (Nikolayevk a, Krasnogorsk region) to 310 μR/hr (Zaborye, Krasnogorsk region).

In the territories of Gordeyev, Zlynkov, Klintsy and Novozybkov regions of the Bryansk oblast where the level of cesium-137 pollution is 15-40 Ci/km^2 the local dose of gamma radiation is from 29 μR/hr (Bezhkov Zlynkov region) to 170 μR/hr (Kozhany Gordeyev region).

In 18 regions of Bryansk, Kaluga, Orlov, and Tula oblasts with a surface cesium-137 pollution level of 5-15 Ci/km^2 the local dose of gamma radiation, according to the results of regular measurements at 20 stations and in expeditionary investigations, were from 18 (Yasenevka, Bryansk oblast) to 65 μR/hr (near Guto-Koretskoye, Bryansk oblast).

In 16 oblasts of the Russian Federati on (Belgorod, Bryansk, Voronezh, Kaluga, Kursk, Leningrad, Lipetsk, Nizhegorod, Orlov, Penzen, Ryazan, Saratov, Smolensk, Tambov, Tula, and Ulyanovsk) as well as the republics of Mordoviya and Tatarstan, with a surface cesium-137 pollution density of 1-5 Ci/km^2 the local gamma radiation dosage, from the results of regular measurements at 49 stations, was from 9 to 29 μR/hr.

There were no noticeable changes in the radiation situation in the areas of atomic power plants and other radiation-hazardous facilities, compared with previous months. The levels of local gamma-radiation dosage in regions in the 100 km observation zones of atomic power plants, the Mayak production association, the Krasnoyarsk mining and chemical plant, the Siberian chemical plant, and sites of buried radioactive wastes were from 8 to 20 μR/hr. These values correspond to fluctuations in the natural gamma radiation, and are characteristic for the environment surrounding these facilities.

Project To Restore Ozone

957A0075 Moscow ZEMLYA I VSELENNAYA in Russian No 6, Nov-Dec 94 pp 33-35

[Article by M. M. Derkovskiy, Tsiolkovskiy Academy of Cosmonautics. First paragraph is introduction in source text.]

[FBIS Translated Text] Russian scientists have developed a number of measures which will restore the ozone layer over a limited area in any region of the Earth. The problem of preserving the ozone layer is an extremely urgent one, as our readers know (ZEMLYA I VSELENNAYA, No 1, 1991; Nos 2 and 3, 1992; No 5, 1993).

The ozone layer protects all life on Earth from the lethal effect of ultraviolet solar radiation, preventing it from reaching the Earth's surfaces in amounts which would be a health hazard. Ozone forms a fragile screening layer around the Earth, and if it is were compressed to atmospheric pressure, it would have a thickness of only a few millimeters. Scientific and technical progress and the economic activity of man has become very powerful, and by ignoring the consequences, it has begun to affect global natural processes. Atmospheric, geological, and genetic processes directly linked with the evolution of life on Earth have acquired the status of urgent and practical problems. The future of humanity as a civilization, the future of our children and grandchildren depend on the solution to these problems. One such problem is restoration of the ozone layer.

The main causes for the destruction of the ozone layer are emissions of large quantities of fluorocarbons and chlorocarbons, as well as a number of other organic compounds which pose a threat to ozone. In September 1987 the Montreal International Protocol was approved, which recommends halting emissions of ozone-destroying substances into the atmosphere. These substances are mainly used in refrigerators. Despite the fact that several countries of the Montreal protocol have complied with the protocol, the amount of ozone in the atmosphere has continued to drop, and the size of the ozone hole in the Antarctic has increased substantially in recent years. The ozone layer has become thinner over a number of countries: Argentina, Chile, New Zealand, Australia...it has gotten thinner over Arctic regions as well.

When we were invited to participate in the First International Conference on the Commercialization of Environmental Protection Technologies (Moscow, 12-14 September 1994) we sent the official request to the joint Institute of Problems in the Control of Biological Objects, which is addressing the protection of the biosphere by creating an additional ozone shield. Specific solutions have been found by the authors in the development of the principal issues of implementing a patent for "a combined Derkov method of restoring the ozone layer." These solutions can now be used to implement a technology to protect regions subject to intensified exposure to biologically dangerous ultraviolet radiation due to destruction of the ozone layer.

The method includes delivering reagents to given altitudes with an aircraft. Initially several balloons or dirigibles were proposed. However, safety considerations regarding the transport of ozone and the absence of the ability to distribute it in space led to a rejection of this type of aircraft. The engine fuel is a mixture of hydrogen and oxygen of a specific composition. The combustion products that are formed (hot water vapor) enter the atmosphere from the engines at an altitude of up to 25 km. As a result of photochemical reactions, with the participation of reagents ejected from the aircraft, an additional amount of ozone is formed. To increase the effectiveness of ozone production on-board microwave generators are used which create a plasma discharge in the wake of the aircraft. However, even in this case, without the participation of reagents the ozone-forming process is too slow. The changes are monitored by measuring systems which monitor the ozone layer and ultraviolet radiation as they occur. The procedure of ejecting reagents and the composition of reagents is not discussed because all of this is "know-how."

A patent was recorded on 15 April 1993 for this invention. The method provides for obtaining additional amounts of ozone based on water vapor ejected by hydrogen-oxygen engines as a combustion product. As it enters the rarified

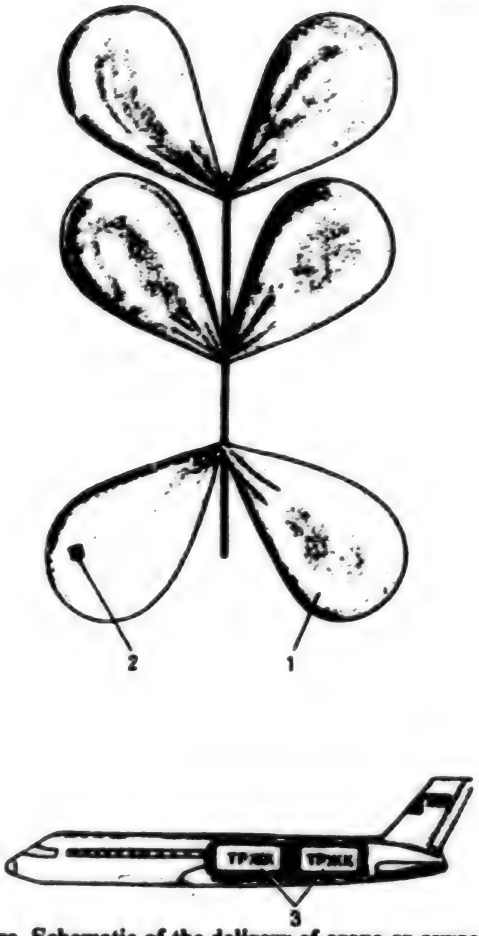


Figure. Schematic of the delivery of ozone or oxygen to the upper layers of the atmosphere with the initially proposed use of a balloon.

Key: 1. transportable vessel of liquid oxygen; 2. ozone or oxygen; 3. device to open the vessel.

atmosphere the steam separates into hydrogen, which leaves the atmosphere, and the OH group, which participates in the formation of ozone when exposed to ultraviolet radiation. However, under natural conditions this process develops extremely slowly. The effect is insignificant. The "combined method" that we have proposed more than doubles the production of ozone. An authors' group was formed to implement this project. The group includes specialists from three scientific centers: The Tupolev Aviation Scientific and Technical Complex (the main complex designer is V. A. Andreyev, candidate of technical sciences, and the deputy chief designer is Yu. N. Popov), the Central Aerological Observatory (S. P. Perov, candidate of physical and mathematical sciences), and the Karpov Physico-Chemical Institute (S. F. Timashov, doctor of physical and mathematical sciences).

The decision was made to create a special flying laboratory to monitor the state of the ozone layer, atmospheric pollution, radiation, and varied extreme occurrences. The main designer of the flying laboratory is A. L. Pukhov, a candidate of technical sciences at the Tupolev Complex.

The laboratory is based on a TU-144 supersonic aircraft with hydrogen-oxygen engines designed by Academician N. D. Kuznetsov. The exhaust gases of these engines consist of water vapor. In addition to the research equipment used in the course of an experiment, the aircraft may also have special equipment, including tanks with liquid oxygen, vessels with chemical reagents, and an ozonizer and microwave generators to create a plasma discharge in the wake of the aircraft. The results of these complex actions will be monitored by ground-based instruments that record ultraviolet radiation that is dangerous to living organisms.

The effect of all these actions to create additional ozone in a limited space was verified in laboratory and insitu conditions. The large flight range of the supersonic aircraft will make it possible for studies to cover any region of the globe.

Estimating Seismic Effect of Underground Explosion

957A0067A Novosibirsk PRIKLADNAYA MEKHANIKA I TEKHNICHESKAYA FIZIKA in Russian No 6, Nov-Dec 94 (manuscript received 7 Aug 92, after revision 24 Dec 93) pp 3-11

[Article by A. S. Bykovtsev and D. B. Kramarovskiy, Tashkent; UDC 550.348+539.375]

[FBIS Abstract] A new approach is proposed for evaluating the seismic effect in the ambient medium created by underground explosions, resulting in the formation of a radial system of fractures, by mathematical modeling of the processes involved, making it possible to ascertain such parameters as fracture length and separation in the affected medium. The traditionally used experimental and computational methods are reviewed and their shortcomings are listed. A more physically sound model of such an explosion, for example, must take into account the finite (rather than infinite) length of a line charge and its different orientation relative to the ambient medium. The series of assumptions made in formulating a three-dimensional model of such an underground explosion is outlined. Formulas are first derived for characterizing an individual explosion, but such explosive work usually involves detonation of a large number of such charges (such as 24 x 8, with simultaneous detonation of 24 charges with a delay 0.025 s). An appropriate model is formulated by application of the superposition principle (the total field created by the detonation of these charges is the sum of the individual wave fields on the assumption that the detonation of one charge exerts no influence on the nature of transpiring of the explosive process of another charge). Accordingly, the parameters of the radial fractures arising along the line are determined using the same expressions as if a single charge was involved. Theoretical seismograms make it easy to detect sectors corresponding to the arrival of seismic waves from each delayed group, thereby making it possible to analyze the wave field both as a whole and separately for each delayed group. Two different layouts of schemes for the triggering of such multiple charges are examined: transverse rows and longitudinal rows. The seismic effect from triggering explosive charges in the first case is greater than in the second case. This is an important finding because in accordance with current instructions the first scheme is usually employed. Figures 7; references: 19 Russian.

Problems and Prospects of Using Enzymes in Environmental Analysis

957A0090A Moscow ZHURNAL ANALITICHESKOY KHIMII Vol 49 No 5, May 94 (manuscript received 19 Apr 93) pp 452-462

[Article by Ye.B. Nikolskaya, G.A. Yevtyugin, and T.N. Shekhovtsova, Moscow State University imeni M.V. Lomonosov, Moscow, and Kazan State University, Kazan; UDC 543.866]

[FBIS Translated Text] The properties of enzymes, especially their high selectivity and sensitivity as catalysts of reactions involving certain biologically active materials, has made it possible to use them to analyze systems with complex compositions such as objects present in the environment.[1,2]

In this article, the possibilities of using enzymes in analyzing objects present in the environment are assessed by way of the example of specific enzyme systems, and ways of expanding the set of identifiable components and enzymes that may be used in the determination process are identified.

Water, air, soil, and plants are the most frequently analyzed objects present in the environment. The main complicating factor of the analysis is the need to identify microquantities of toxicant against the background of a complexly structured matrix that in many cases includes inorganic and organic substances in quantities hundreds or thousands of times exceeding that of the component being identified. In such situations, laborious and complicated preparation of samples is generally required before the object can be analyzed. In cases where enzymes with high catalytic specificity with respect to reactions of the component being identified are used, the said preparation is either greatly simplified or not required at all. One example is the identification of urea in the water of swimming pools, soil, etc., by means of indicator sets based on urease, a highly specific substrate of which is urea.[3]

Correct use of enzymes in the analysis of objects present in the environment requires knowledge (or study) of their substrate-inhibitor specificity under conditions as close as possible to those under which the identification will be conducted. From the standpoint of substrate-inhibitor specificity, there is no doubt as to which enzymes on the huge list of currently known enzymes (the enzyme classification alone contains more than 2,500) offer promise for use in analyzing environmental objects.[4]

Table 1 presents examples of enzymes whose use in analysis may significantly expand the list of identifiable environmental objects.

Table 1. Enzymes Promising for Identification of Specific Environment-Polluting Substrates

Class	Enzyme	Substrates
1. Oxidoreductases		
1.2.1.1	Formaldehyde dehydrogenase	Formaldehyde
1.2.1.2	Formiate dehydrogenase	Formiates
1.2.1.3	Aldehyde dehydrogenase	Benzaldehyde
1.2.1.7	Benzaldehyde dehydrogenase	Benzaldehyde
1.2.1.8	Betaine aldehyde dehydrogenase	Betaine aldehyde
1.4.3.4	Monoamine oxidase	Primary, secondary, and tertiary monoamines
1.6.6.1	Nitrate reductase	Nitrates
1.6.6.4	Nitrite reductase	Nitrites
1.8.3.2	Thiol oxidase	Thiols
1.8.7.1	Sulfide reductase	Hydrogen sulfide
1.8.99.1	Adenylsulfate reductase	Sulfites
1.10.3.4	*o*-Aminophenol oxidase	*o*-aminophenol
1.14.18.1	Monophenol monooxygenase	Diatomic phenols
2-Transferases		
2.1.1.25	Phenol-*o*-methyltransferase	Phenol
2.1.1.26	Iodophenol methyltransferase	Iodophenol
2.4.1.1	Phosphorylase	Orthophosphates
2.8.1.1	Thiosulfate-sulfite-transferase	Cyanide, thiosulfate
Hydrolases		
3.1.1.10	Tropine esterase	Atropine, cocaine, and other choline esters
3.5.1.5	Urease	Urea
3.8.2.1	Diisopropyl fluorophosphatase	Diisopropyl fluorophosphate, organophosphorus compounds
3.8.1.1	Alkylhaloidase	Chloralkanes, bromoalkanes
3.8.1.2	2-Haloid acid-adehalogenase	L-2-Halogen acids
Lyases		
4.2.99.8	Cysteine	Hydrogen sulfide
4.4.1.9	*b*-Cyanoalanine synthetase	
4.4.1.10	Cystine lyase	Sulfites

Enzymes permitting identification of an entire class of compounds (or part of a said class) or, finally, an individual compound may be singled out. The enzyme aldehyde dehydrogenase, for example, may be used to identify all aldehydes, and benzaldehyde may be used to determine benzaldehydes; however, betaine aldehyde dehydrogenase can only be used to identify betaine aldehydes. Alcohol dehydrogenase may be used to identify alcohols, alcohol oxidases may be used to identify primary alcohols, and arylalcohol oxidases may be used to identify aromatic primary alcohols.

The list presented could undoubtedly be continued, especially if consideration is given to the fact that substrates constitute only a small part of the materials that may be identified by using enzymes. The set of compounds that are effectors of enzyme-substrate systems, i.e., inhibitors and activators that can in many cases be identified by enzyme methods with low detection thresholds and rather high selectivity, is significantly broader. In reality, however, of the long potentially possible list of enzymes that would appear very promising for analytical purposes, only about 20 have found extensive practical application,[5] and of those, only 8-10 are in an immobilized state. The problem is that one extremely important condition, i.e., convenience of fixing the analytic signal of the enzyme reaction, must be met before an enzyme can be of practical use in analysis. This implies the existence of a method of determining an enzyme's activity, the possibility of developing the instrumentation required to implement the method, stability of the enzyme, a readily available source of the enzyme, relative simplicity of obtaining the enzyme, the ability to use the enzyme repeatedly, and other factors. With regard to analysis of environmental objects, the aforementioned list must be expanded to include the possibility of automating the analysis and conducting it quickly and simply. After all these conditions have been met, all that remains in the analyst's hands is a brief list of enzymes that taken as a whole, cannot satisfy ecologists' demands regarding identification of a huge number of priority environmental pollutants, including organochlorine pesticides, energy-consuming hydrocarbons, nonionogenic and ionogenic surfactants, etc.

Some of the aforementioned problems of enzyme-based analysis methods will now be examined in greater detail.

Method of determining the enzyme activity and possibility of developing the instrumentation required for it. These two problems are closely related to one another. Creating a fundamentally new instrument or device especially for a specific enzyme reaction is complicated and expensive. It is much more advantageous and much simpler to adapt an already existing device for enzyme-based analysis methods. In enzyme reactions involving oxidase or dehydrogenase, in which oxygen serves as one of the substrates, for example, an oxygen-sensitive amperometric electrode is generally used as a detector. The Clark electrode was the first enzyme electrode. Glucose oxidase was immobilized on its surface.[6] Later, medical instruments for determining glucose, lactic acid, ethanol, L-lysine, saccharose, and cholesterol were developed on the basis of amperometric electrodes and immobilized enzymes.[7-11]

Numerous detection methods exist for enzyme reactions during which a change in pH occurs, including a photometric method in which acid-base indicators are used[12] and potentiometric methods involving the use of pH-measuring electrodes[13-15] or pH-sensitive ion-selective field-effect transistors.[16-18] Hydrolases are among the enzymes whose activity can be thus determined.

Gas-sensitive electrodes have become widely used in the past few years. They may be used to track the formation or consumption of gaseous or volatile enzyme reaction components such as ammonia, hydrogen sulfide, and carbon dioxide.[19-22]

Chemiluminescence methods have an extremely high sensitivity and make it possible to monitor the rate of enzyme reactions involving luciferase, for example.[23-25]

Finally, spectrophotometric methods of detecting the rate of enzyme processes are worthy of mention. They remain important above all for oxidoreductases, especially nicotinamide-adenine dinucleotide [NAD]-dependent enzymes, hydrolases, and several other classes of enzymes. They are irreplaceable in the development of test methods, including visual tests methods, and are used in new-generation sensors based on optical fibers (optrodes).[26,27]

Other detection principles (piezoelectric, conductometric, photocell, and fuel elements) have not yet been widely used in identifying ecotoxins, although they have tangible advantages over traditional principles in certain cases.[28-31]

In many cases, bienzyme and polyenzyme systems are used to increase the enzyme method's selectivity and also to permit the use of previously developed detection methods. The oxidase-peroxidase system is a classic example.[32-35]

$$\text{Substrate 1} + O_2 \xrightarrow{\text{oxidase}} \text{Product 1} + H_2O_2$$

$$H_2O_2 + \text{Substrate 2} + 2H^+ \xrightarrow{\text{peroxidase}} \text{Product 2} + 2H_2O.$$

PHotometric[36] or electrochemical[37,38] methods may be used to observe the peroxidase reaction depending on the substrate selected for the said reaction (substrate 2).

Low stability of enzymes during the reaction process, in storage, and upon a change in the conditions of an enzyme reaction (temperature or pH). This problem is the Achilles heel of using enzymes in practice. The more stable enzymes, for example, glucose oxidase and cholinesterase from equine blood serum and erythrocytes, etc., have therefore been used most extensively.

At the same time, however, attempts have been made to stabilize enzymes' activity by using special stabilizers, mainly by developing methods of immobilizing enzymes that generally also stabilize their activity. Other advantages have resulted from such attempts, including multiple use of one and the same batch of enzyme preparation and the possibility of creating enzyme-based analytic devices (reactors, electrodes, etc.).

Complexity of obtaining many enzymes in purified or partially purified form and their accordingly high cost. As before, this remains a significant barrier to using enzymes.

Commercial production of many enzyme preparations (glucose oxidase, peroxidase, catalase, phosphatase, cholinesterase, urease, and others) has recently been launched, however, and the possibility of using unpurified enzymes in the form of tissue sections, homogenates, microorganisms, etc., has made enzyme-based analysis methods much simpler and much less expensive.[39-44] The ability to use a system of enzyme reactions simulating a toxicant's effect on the body as a whole is an important aspect of using microbial and tissue sensors and tests. Biochemical oxygen demand [BOD]-sensors,[45-48] cyto- and phytotoxicity sensors,[49-51] aniline-based microsomal electrodes, and determination of chemical compounds' mutagenic and carcinogenic properties by using a mutant strain of salmonella (the Ames test),[54] including the corresponding microbial sensor,[55-57] may be cited as examples.

Examples of the use of enzyme-based analysis methods in ecology will be examined. The examples presented below may tentatively be divided into three groups. The first includes the use of enzymes that have already been used in ecology. The second includes examples of the use of enzymes that have been used as the basis of methods of determining ecotoxins under model conditions. These enzymes may be used to analyze real objects. The third group includes examples of the use of enzymes that appear to be promising for use in ecology in the future.

Above all, the cholinesterases acetylcholinesterase (classification No. 3.1.1.7) and cholinesterase (classification No. 3.1.1.8) should be mentioned. The enzymes in this group have become widely used in medicine and veterinary medicine to diagnose poisoning by organophosphorus compounds and carbamate.[12,58] Cholinesterases are also used in ecology to determine trace quantities of organophosphorus and carbamate pesticides in water, soil, plants, and foodstuffs.[59-61] Salts of quarternary ammonium bases, selected aromatic chlorine compounds, heavy metal salt compound, etc., also have an inhibitory effect on cholinesterase.[12,58-66] If all these components are present in an object undergoing analysis, the total effect of a reduction in enzyme activity is observed. This has, for example, made it possible to estimate the total (overall) toxicity of water in the Paris water supply system based on a decrease in cholinesterase activity. It has been demonstrated in one publication[67] that the toxicity of salts of copper, mercury, Trichlorphon, fozalon [transliteration], metaphos [methyl parathion], and other compounds in the microalgae photosynthesis processes are rather well correlated with one another as estimated by inhibition of delayed fluorescence of the chlorophyll of *Chlorella vulgaris* and the inhibiting effect of these substances on the cholinesterase of equine blood serum.

Eliminating the effect of heavy metals or irreversible inhibitors on cholinesterase and thereby increasing the selectivity of determining several types of cholinesterase inhibitors does not present any special difficulty. Increasing the pH to 8 practically eliminates the effect of heavy metal ions, and in the presence of a substrate in high concentration, the enzyme becomes insensitive to irreversible inhibitors.

Cholinesterase's sensitivity to an active agent may also be increased by selection of the cholinesterase source. As has been shown elsewhere,[68,69] cholinesterase from a homogenate of fly heads is more sensitive to the effects of certain pesticides, for example, dichlorovinyldimethylphosphate, than is cholinesterase from other sources. This has made it possible to reduce the detection threshold of the said pesticide by a factor of 100.[68] Although this cholinesterase is extremely unstable in a nonimmobilized state, when it is immobilized in a gelatin membrane, its stability increases both during use and storage.[69] In addition, cholinesterase from fly heads is easily induced to react by using TMB-4, i.e., a monohydrate of 1,1-trimethylene-bis(4-oximinomethyl)-pyridinium dibromide, after the action of organophosphorus compounds, which allows it to be used multiple times.

In addition to depending on the enzyme's source, the sensitivity with which cholinesterase inhibitors are determined also depends on the conditions under which the process is conducted and the method used to detect it (in the case of a biosensor, it depends on the nature of the transducer). Other publications[70-72] have reported the development of a cholinesterase biosensor consisting of an amalgamated silver electrode and nitrocellulose membrane containing butyrylcholinesterase derived from equine blood serum. The current from the reduction of mercury mercaptide, which is formed on the sensor's surface from thiocholine (a product of the enzyme hydrolysis of butyrylthiocholine) serves as an analytic signal. The said detection method and analysis conditions have resulted in high-sensitivity determination of cholinesterase inhibitors (for example, the detection threshold of Trichlorphon is 1×10^{-11} mol/l). This high biosensor sensitivity is likely linked to the symbasic effect of two factors—adsorption of organophosphorus compounds on hydrophobic cellulose nitrate and the synergic effect of the alkaline earth metal ions (cholinesterase activators) present in the solution.

Cholinesterase has also been used as a basis for creating continuous-type alarms indicating pollution of water and air by organophosphorus compounds and carbamates (which are now being manufactured by CAM in the United States[73,74] and SIMTEC NAIAD in Great Britain[75]), sensors for monitoring water quality (in France)[76-79], indicator tubes and papers (in Sweden, Italy, and the United States)[80-81]), and test kits (at the Kazan University's Ecology Department).[82] Use of cholinesterase and chromatographic detection of *tert*-butyl alcohol, which is an enzyme hydrolysis product, to determine the total amount of organophosphorus pesticides is one of the water quality control methods recommended for use by the U.S. Environmental Protection Agency.[60] Cholinesterase reactors for high-performance liquid chromatography and flowthrough injection analysis with photometric detection[83-85] permit quantitative estimates of trace amounts of pesticides in foodstuff.

Urease is currently being used mainly to determine urea, a specific substrate, for biomedical purposes and also to monitor water in swimming pools. In addition, methods of determining urease inhibitors, i.e., salts of heavy metals and fluorides, involving potentiometric[86-89] and photometric determination[90] have also been described. A urease reactor with an enzyme immobilized on porous glass was used to

estimate the total amount of heavy metals contained in Moscow Oblast's water supply system and well water. The detection thresholds of most toxic metals is 1 x 10^{-8} mol/l (1 x 10^{-10} to 1 x 10^{-9} mol/l for iron).[90] Selective determination of individual metals has not yet been successful.

Monoamine oxidase derived from the mitochondria of pig livers (classification No. 1.4.13.4) has been used to determine hydrogen sulfide in the wastewaters of a number of enterprises in Riga.[91] An enzyme sensor based on an electrode with a gas gap was used for this purpose. In addition, an analogous sensor has been used to determine an entire series of nitrogen-containing materials, including phenylhydrazine and benzimidazole and its derivatives (plant growth regulators) in model systems.[21]

Various amine oxidases in mono- and polyenzyme sensors have been used for determining the freshness of fish and meat.[92-95]

Horseradish peroxidase (classification No. 1.11.1.7) has long been used in analytic methods to determine a number of organic amines, phenols, and hydrogen peroxide,[96] which are natural substrates of the enzyme. In addition, its high hydrogen sensitivity and the ease of determining the catalytic activity of peroxidase by photometric, chemiluminescence, fluorometric, and electrochemical detection of the rate at which synthetic substrates (derivatives of benzidine, aminosalicylic and *n*-oxyphenylpropionic acids, phenylenediamine, etc.) are oxidized make horseradish peroxidase a convenient marker in immunoenzyme analysis methods, including its use in determining herbicides such as atrazine and 2,4-dichlorophenoxyacetic acid and its salts,[97] as well as for detecting reactions catalyzed by oxide reductases.[32-38]

A whole series of methods have been developed for determining organic and inorganic horseradish peroxidase inhibitors, i.e., ions of various metals,[36] cyanides, hydrogen cyanide,[98-99], sulfur-containing organic compounds,[100] and activators, i.e., nitrogen-containing compounds (imidazoles, triazoles, etc.) with detection thresholds of 1 x 10^{-8} to 1 x 10^{-5}.[101]

The most interesting are methods for determining such toxic peroxidase inhibitors as mercury, cadmium, and bismuth. The detection thresholds for cadmium and bismuth are 5 x 10^{-4} µg/ml and 2 x 10^{-4} µg/ml (1 x 10^{-9} mol/l), respectively.[36] Mercury's inhibiting effect increases when thiourea is added to the enzyme system, which results in a significant increase in the sensitivity and selectivity of determining mercury. Increased sensitivity is also facilitated by purposive selection of the reducing agents used in mercury-inhibited peroxidase oxidation reactions. Thus when *o*-dianizidine is replaced by 3,3', 5,5'-tetramethylbenzidine, the mercury detection threshold is reduced from 1 x 10^{-3} µg/ml (5 x 10^{-11} mol/l) to 3 x 10^{-7} µg/ml (1 x 10^{-12} mol/l).[102] Determination is hindered only by cadmium and bismuth in 1,000- and 10,000-fold excesses, respectively.

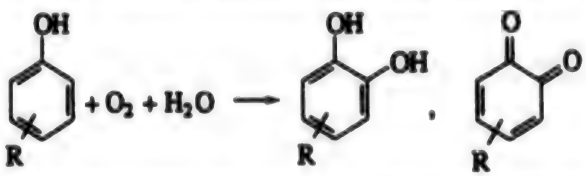
The method developed on the basis of peroxidase oxidation of *o*-dianizidine and tetramethylbenzidine is used to determine mercury in sea and river water. Use of thiourea makes it possible to determine the total amount of mercury in an analysis object regardless of the ion states or form of organic compounds in which the mercury may be.[36]

A test device in which immobilized horseradish peroxidase is used to determine mercury in waters at the level of the maximum permissible concentration [MPC] under field conditions has been created.

In addition to the aforementioned enzymes that have already been used to analyze environmental objects, one could name an entire series of enzymes that have been used in developing methods of determining various substances in model systems. And these methods are ready for use in analyzing real objects.

Besides peroxidases, various phenoloxidases and tyrosinases may be used to determine phenols.

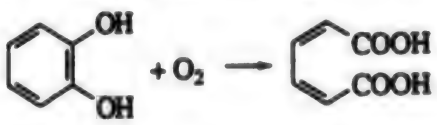
In the first case, various phenoloxidases that are generally of plant origin, for example, polyphenoloxidase (classification No. 1.14.18.1) derived from true mushrooms or potatoes and immobilized by glutaraldehyde on the surface of a Clark electrode, are used.[40,103] Under the effect of molecular oxygen, this enzyme catalyzes the oxidation of mono- and diatomic phenols into the corresponding polyphenols and quinones without the formation of hydrogen peroxide.[104]



The method's sensitivity exceeds that of the corresponding methods of spectrophotometric determination of phenol with 4-aminoantipyrine.

A tyrosinase potentiometric sensor based on measuring the potential of the mediator reduction-oxidation pair $Fe(CN)^{4-}_6/Fe(CN)^{3-}_6$ makes it possible to determine phenol in concentrations ranging from 3.8 x 10^{-7} to 1 x 10^{-4} mol/l.[105]

Methods and sensors using sections and homogenates of the reproductive substance of mushrooms[40] or yeast cultures[106,107] instead of purified enzymes have also been described. In the latter case, oxidation of phenols in the second stage includes destruction of the aromatic ring; the detection threshold for phenol is 2 mg/l.



In addition to oxidases of plant origin, ceruloplasmin (classification No. 1.16.3.1), which is a blood hemoprotein, is also being used to detect aromatic amines and aminophenols.[108] The detection threshold for *n*-phenylenediamine is 1 x 10^{-5} mol/l.

All of the aforesaid methods possess low substrate specificity and are intended for analyzing process waters and wastewater because they make it possible to determine phenols and their chlorine derivatives at the level of the MPC (*n* x 10^{-3} mg/l) without preliminary concentration.

In one publication,[109] it has been proposed that sodium-potassium-dependent adenosinetriphosphatase be used to

determine contaminants in aqueous media. The inhibiting effect of the following has been established: silver, mercury, copper, cadmium, aluminum, nickel, and cobalt salts; fluorides; and aromatic chlorine, organophosphorus, and carbamate pesticides. The values found for the median inhibitory concentration [I_{50}], i.e., that concentration of toxicant causing 50 percent inhibition of the enzyme, ranged from $n \times 10^{-7}$ mol/l (for silver, cadmium, copper, and mercury) to 1×10^{-2} mol/l (for the Malathion insecticide karbofos). No toxic effect of sodium chloride, sodium sulfide, or eserine has been established. It has been proposed that the method be used to estimate the total pollution of waters.

In addition to other hydrolytic enzymes, alkaline phosphatase (classification No. 3.1.3.1) and acid phosphatase (classification No. 3.1.3.2) are used to determine effectors. Methods of determining lead (detection threshold, 1×10^{-4} μg/ml or 5×10^{-10} mol/l),[110] beryllium (detection threshold, 1×10^{-6} mol/l),[111-113] and thiol-containing compounds (thiocresols, thioaniline, thiosalicylic acid, etc., with detection thresholds of 8×10^{-8} to 4×1^{-4} mol/l)[114] have been based on the inhibiting effect of the said elements/compounds on alkaline phosphatase. Phosphorus-containing complexes may be detected with detection thresholds of 3×10^{-8} to 1×10^{-6} mol/l based on their activating effect on alkaline phosphatase.[115] Also interesting is a method of determining metal ions, i.e., enzyme cofactors, based on regeneration of the enzyme activity of the corresponding apoenzymes. A method has thus been developed for determining microquantities of zinc based on its activating effect on the apoenzyme of alkaline phosphatase.[116]

The inhibition of acid phosphatases of plant origin derived from potato eye tubers and wheat sprouts by fluoride, tungstate, and molybdate ions has been used to develop determination methods with the following detection thresholds: fluoride ions, 2×10^{-6} μg/ml (1×10^{-10} mol/l); tungstate ions, 1×10^{-3} μg/ml (4×10^{-11} mol/l); and molybdate ions, 3×10^{-4} μg/ml (2×10^{-9} mol/l).[117] Methods have been proposed for determining tungstate ions in soil samples as well as for detecting (at the level of the MPC) fluoride ions formed during the decomposition of highly toxic fluorine-containing organic compounds.

Papain (classification No. 3.4.22.2) is used to determine its inhibitors, i.e., heteroorganic compounds.[118]

Sulfur dioxide is determined by several enzyme reactions: by the reduction of sulfite reductase ((classification No. 1.8.1.2) to sulfides or by its oxidation to sulfates in the presence of sulfite oxidase (classification No. 1.8.3.1) or sulfite dehydrogenase (classification No. 1.8.2.1). When oxidase is formed, hydrogen peroxide forms

$$SO_3^{2-} + O_2 + H_2O \longrightarrow SO_4^{2-} + H_2O_2,$$

that is capable of electrochemical oxidation on inert electrodes. A series of methods for determining sulfites, including sulfites in natural waters, soil, and air,[119-124] is based on this fact. Electrochemical detection permits the detection of sulfur dioxide in concentrations of 1×10^{-6} to 1.5×10^{-4} mol/l in water and 5-600 ppm in a gaseous phase. Pyruvate and oxalocetate ions (sulfite oxidase inhibitors) and substances capable of oxidation on the anode together with hydrogen peroxide (ascorbic acid) interfere with the determination process. In addition, hydrogen peroxide may partially oxidize sulfite ions and thereby raise the detection threshold. Improvements in electrochemical detection of the enzyme process include additional membranes preventing the mass transfer of easily oxidized impurities to the electrode surface and the use of mediators of electron transfer (1×10^{-6} to 1×10^{-4} mol/l $K_3Fe(CN)_6$), including during measurement in a flow. The analyzers that have been developed make it possible to perform as many as 100 analyses in an hour. The sulfite oxidase membranes may be stored for 3 weeks. Spectrophotometric and fluorometric methods of determining sulfur dioxide through the use of enzymes have also been described.

In one work,[125] it has been proposed that the bienzyme system sulfite oxidase-NADH peroxidase (classification No. 1.11.1.1) be used to lower the detection threshold and that the sulfite (sulfur dioxide) concentration be determined based on the decrease in concentration of NADH

$$H_2O_2 + NADH + H^+ \longrightarrow NAD^+ + 2H_2O.$$

The concentration of NADH is determined spectrophotometrically at 340 nm and fluorometrically at 467 nm. The calibration graph is linear in the range of concentrations from 0.7 to 10 μg/ml sulfite ions. When an aqueous solution of triethanolamine is used as the absorber, the amount of sulfur dioxide in air can be measured.

Bienzyme systems are used in an analogous manner to determine formaldehyde and formic acid. In the first case, formaldehyde is oxidized to formic acid in the presence of formaldehyde oxidase (classification No. 1.2.1.46), and diaphorase regenerates NAD^+ and forms a colored product (formazan) whose optical density is measured at 500 nm

$$CH_2O + NAD^+ \longrightarrow HCOOH + NADH,$$
$$NADH + INT \longrightarrow NAD^+ + \text{formazan},$$

where INT = chloride 2-(4-iodophenyl)-3-(4-nitrophenyl)5-phenyltetrazolium.

In the second case, formiate dehydrogenase (classification No. 1.2.1.2) is paired with diaphorase

$$HCOOH + NAD^+ \longrightarrow CO_2 + NADH + H^+.$$

In addition to formazan, fluorogenic resorufin (λ_{max} = 590 nm) may be used for detection

$$NADH + \text{resazurin} \longrightarrow NAD^+ + \text{resorufin}.$$

In addition to the aforementioned examples, the following oxide reductases have been used for the determination of inhibitors: cytochrome b_2 oxidase (to determine azides, hydrogen sulfide, and cyanides[126]) and alcohol dehydrogenase (to determine cyanides[127,128] and heavy metal salts[129]).

Of those enzymes that are promising for use in analyzing environmental objects, we will focus on two groups: carboxyl esterases and cytochrome P-450.

To some measure, carboxyl esterases are already being used in toxicologic analysis in conjunction with cholinesterase.[130-133] Data in the literature confirm that carboxyl esterases derived from various biologic sources possess extensive substrate specificity and sensitivity to inhibitors. The sources of carboxyl esterase are extremely diverse: plants, microorganisms, insects, mammals, and fish. Even carboxyl esterases obtained from more or less homogeneous sources, for example, mammal livers, possess different properties, which permits extensive variation of the said enzymes' analytic capabilities. Two carboxyl esterases derived from the liver of the reindeer, which are referred to as "fast" and "slow,"[134] possess different substrate specificity. The Malathion insecticide karbofos is a specific substrate for "slow" carboxyl esterase, whereas for "fast" carboxyl esterase, it is only a reversible inhibitor of moderate strength.

Carboxyl esterase derived from mouse liver is highly sensitive to armin [as published] and dimethyl dichlorovinyl phosphate [DDVP or dichlorovos]. The stability of this enzyme increases significantly upon immobilization,[68] and it may be used repeatedly to determine irreversible organophosphorus inhibitors by reactivating it with TMB-4. The high selectivity of these enzymes to the effect of a number of organophosphorus pesticides (a higher selectivity than that of cholinesterases) makes them suitable for use in determining the said pesticides. Moreover, combining carboxyl esterases and cholinesterases in an analysis makes it possible to identify groups of pesticides and, sometimes, individual pesticides.[135]

The great diversity of carboxyl esterase substrates makes it possible to select the optimum detection method. As in the case of cholinesterase, the colorimetric (including visual) and electrochemical versions of the "ΔpH" method[82] may be used to determine the activity of carboxyl esterases. One plus is the high activity of a carboxyl esterase's active center (in some cases, a higher activity than that of cholinesterase). Use of bienzyme systems consisting of cholinesterase and carboxyl esterase will likely eventually be extremely promising.

Of the nonspecific oxidases, cytochrome P-450 possesses the broadest analytic capabilities in relation to contaminants of objects of the environment. In living organisms, cytochrome P-450 is located in the microsomes of the endoplasmic reticulum of the hepatocytes and plays an important role in detoxication processes by participating in the hydroxylation of numerous substrates[136,137]

$$SH + H^+ + NADPH + O_2 \longrightarrow S\text{–}OH + NADP^+ + H_2O_2.$$

The following may serve as substrates (SH): aromatic amines, including aniline, acetanilide, diphenyls, benzpyrene, and selected drugs (codeine, amidopyrine, paracetamol, phenobarbital, etc.). In addition to hydroxylation, the the alkyl groups in N-substituted anilines and anisole derivatives are split off, and the thiol and sulfide fragments (phenothiazines) undergo oxidation. The substrate is regenerated in microsomes by NADP-cytochrome P-450 reductase (classification No. 1.6.2.4). Analytic systems based on cytochrome P-450 are now using microsomes (most often, rabbit or rat microsomes), immobilization of which can increase enzyme systems' stability. Gels (gelatin, polyvinylpyrrlidone, and polyacrylamide), sepharose, nylon, cellulose, and cellulose derivatives are among the materials being used as carriers. An electrode described for determining aniline has been described in which the concentration of the enzyme process substrate is determined by the current of the oxidation of *n*-aminophenol, an aniline oxidation product.[138] Gelatin membranes may be stored for 1 year. Cytochrome P-450 retains up to 60 percent of its activity when immobilized. It has been proposed that organic peroxides or hydrogen peroxide, which are also generated in the enzyme process of the oxidation of glucose under the effect of glucose oxidase, be used instead of expensive and unstable cofactor.

Further development of the analytic use of cytochrome P-450 should probably include the use of chromogenic substrates, the development of new enzyme sources such as microbial cultures, and the development of methods of determining cytochrome P-450 effectors (which include such priority environmental pollutants as aromatic chlorine and organophosphorus pesticides and dioxins).

The reduced flavoprotein NADPF must be a part of the oxidation reaction catalyzed by cytochrome P-450. This increases the method's cost significantly and requires, at the very least, systems to regenerate the oxidized flavoprotein to its starting form. A more rational approach, however, appears to be to use organic hydroperoxides or hydrogen peroxide to sustain the enzyme reaction. The addition of oxygen and cytochrome P-450 reductase then become unnecessary.

The potential and progress of using enzyme methods of analyzing objects present in the environment have been considered. The main factors dictating and limiting practical application of enzymes in performing the tasks involved in ecologic-analytic monitoring have been discussed. Examples of the respective methods and instruments have been presented. Those enzyme systems that appear most promising for introduction into the practice of ecologic monitoring in the future have been analyzed.

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